Robert Hindel, PhD, *Editor*

Implementation of the DICOM 3.0 Standard

A Pragmatic Handbook

RSNA | Radiological Society of North America
Founded in 1915

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Introduction

An implementation of the Digital Imaging and Communications in Medicine (DICOM 3.0) standard should have one primary objective: to enable reliable and unambiguous transfer of information objects and action definitions ("services") between heterogeneous systems. Such heterogeneous systems are, for instance, image generating systems such as CT scanners and MR imagers, storage systems such as jukeboxes and servers, image printers, and general or special image processing systems but also proprietary networks. They generate and store information objects in various formats and define actions in various ways. DICOM 3.0 supplies unambiguous definitions that, when used, ensure viable communication.

This simple objective, however, is not easily accomplished. The heterogeneous data formats and action definitions must be converted into the DICOM 3.0 language either by a separate device or by software built into the heterogeneous system. The *info*RAD demonstrations of 1992 and 1993 have shown that external devices can be designed which, equipped with implementations of DICOM 3.0 software, can successfully communicate. Not shown and not intended to be shown was conversion of proprietary information. Commercial PACS installations, however, will require such conversions.

Furthermore, a real-world implementation will deal with several participating nodes called Application Entities (AEs). The Conformance Statement of the standard can be used as a blueprint for system compatibility.

The five chapters are organized in a logical sequence:

Chapter 1	contains statements by key promoters of the standard.
Chapter 2	gives a brief history and explains the essentials of the DICOM 3.0 standard.
Chapter 3	describes the *info*RAD demonstrations as important cooperative projects.
Chapter 4	lists available products in terms of software, hardware and support. It also supplies the reader with statements by major vendors in the PACS market as to their particular approach and strategy for DICOM 3.0 implementation.
Chapter 5	contains supplementary information such as a glossary and comments about related developments.

This handbook does not introduce the reader to the intricacies of the standard, but rather addresses topics that the standard deliberately excludes, namely, conversion of inputs, specific implementation strategies, and integration of many conformant AEs on a network.

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CHAPTER 1
The Significance of the DICOM Standard

The Role of RSNA in Supporting the Implementation and Demonstration of DICOM 3.0

Laurens V. Ackerman, MD, PhD

As you read this handbook, it will be obvious that the setting of the Digital Imaging and Communications in Medicine (DICOM) 3.0 standard, its implementation, demonstration, and final acceptance has been a long process involving a considerable amount of financial and time commitments from a large group of individuals and organizations. This year, the standard and implementation have matured to early adulthood, able to stand by itself as it emerges into the medical imaging world. Dr. Jost provides a good history of the implementation process of the standard in the early 1990s in his chapter "The Role of the Electronic Radiology Laboratory at the Mallinckrodt Institute of Radiology."

As Dr. Jost notes, the RSNA Electronic Communications Committee (ECC) started to work with the American College of Radiology–National Electronics Manufacturers Association (ACR-NEMA) MedPacs ad hoc section for demonstration of the DICOM standard early in 1992. An RFP was formulated for the software implementation of a limited demonstration and circulated by the RSNA, and the Electronic Radiology Laboratory (ERL) at the Mallinckrodt Institute of Radiology was selected. With the approval of the RSNA Board of Directors, the RSNA decided to initially fund the project with the hope that part of the funding would come later from participating organizations. The first year's demonstration at the RSNA scientific assembly and annual meeting in November 1992 consisted of (*a*) a local network of Sun computers that supported the central test nodes connected to the participating vendors by means of a Cisco router and (*b*) a local network set up in the

*info*RAD demonstration area. A considerable amount of work was put forth by the ERL in a very short time to create the first set of software for RSNA '92. The ERL was able to write the software, put together extensive documentation, and hold a users' conference in about 3 months with a simple but robust set of software that functioned with very few errors at the first DICOM 3.0 demonstration.

In 1993, Mallinckrodt Institute of Radiology was again selected by RSNA to write a more sophisticated set of software for the RSNA meeting in November. At that meeting, however, a considerable change was to take place as the ECC decided that all of McCormick Place in Chicago should be networked to help in the demonstration of the standard. RSNA established the Network Operation Center, which consisted of about 20 full-time people and appropriate computer equipment, to support the network. Two networks were constructed. The DICOM network was set up to allow anyone in McCormick Place to participate in the demonstration, but the network was closed to communication from outside McCormick Place. Another parallel network was constructed and was connected to the Internet through a T3 connection. Both networks provided 10-Mbit Ethernet and 100-Mbit FDDI connections. It should be noted that the network setup was accomplished in under 1 week and was the size of, or larger than, that presently in the largest hospital setting. This was accomplished by assembling the wiring, routers, hubs, bridges, and supporting computer systems in a test setting well before the November meeting. Again, the demonstration was very successful.

At the end of RSNA '93, the DICOM 3.0 software was adjusted for software errors found at the meeting and, as of January 31, 1994, was placed on the RSNA and Mallinckrodt ftp servers and made available through anonymous ftp, open to all on the Internet. It was also made available, for media costs, on magnetic tape to those who did not have Internet connections. It was felt at that time that the standard and implementation were robust enough to be used in a commercial setting and that, by releasing the software for free, DICOM would rapidly grow.

Also, because there was one publicly available set of source software, we felt that communication between different systems would be easier if there were one freely available DICOM 3.0 software implementation. This has proven to be the case, as evidenced by the mention of DICOM both in articles and, more importantly, in advertisements in many radiology journals.

For a third year, the RSNA has contracted with Mallinckrodt Institute of Radiology to help with the demonstration of the DICOM 3.0 standard. This year, the RSNA has constructed one large network for all functions at the meeting, the majority of which will serve the DICOM demonstration. The initial testing of whether an organization can connect to the meeting will be performed, not in a large "connectathon" prior to RSNA '94, but over the Internet. We hope that this year DICOM will become an essential, though routine, part of our meeting.

In sum, over the past 3 years, the RSNA's November meeting has become a laboratory for DICOM 3.0, bringing the standard developed by ACR-NEMA into implementation and acceptance by the world of radiology and other areas of medicine. This has been made possible through the financial support of the RSNA and participating commercial vendors, the code developed by ERL, and the cooperation and support of many other individuals and organizations. In the future, we see the RSNA scientific assembly and annual meeting as a laboratory that will foster connectivity with DICOM as the first in a line of successful experiments.

10 The Role of the Electronic Radiology Laboratory at the Mallinckrodt Institute of Radiology

R. Gilbert Jost, MD

For over 10 years, countless devoted individuals have contributed effort and energy toward the development of a standard for storage and transmission of radiologic images. This effort, known as the ACR-NEMA standardization project, has faced its share of difficulties in gaining acceptance. A turning point came in the early 1990s, when some major innovations were introduced. First, a revision of the standard called for the use of networks based on TCP/IP and OSI implementations instead of relying on a physical connection through a unique fifty-pin plug. At about the same time, an important new version of the standard, now known as DICOM version 3.0, was introduced along with significantly enhanced functionality.

In response to these developments, the MedPacs section of NEMA chaired by Dr. Robert Hindel proposed a demonstration, of the standard to promote its acceptance. An ad hoc committee was charged with setting up ground rules for the demonstration. In an innovative development, the committee decided that vendors would not communicate with one another directly but would exchange images through a central exchange point known as a central test node (CTN). The vendors were to communicate with the CTN through their own demonstration prototype node (DPN). Instead of requiring vendors to exchange images directly, vendors could exchange images via the CTN. This permitted a robust demonstration of the standard without requiring prearrangements among the participating companies.

The MedPacs section, in order to facilitate the demonstration turned to Dr. Laurens V. Ackerman, who is now chairman of the Electronic Communication Committee of the Radiological Society of North America (RSNA). Together they realized that the development of a common software layer was important to a successful demonstration of the standard, and on April 11, 1992, they called for proposals from universities to develop the software. About a month later, the committee selected the Electronic Radiology Laboratory at the Mallinckrodt Institute of Radiology to pursue the development.

A flurry of activities ensued during the next 2 months as a development team was assembled under the direction of Steve Moore and the software was prepared. On July 1, 1992, twenty-five vendors agreed to participate in the demonstration at RSNA '92, and on July 15, a workshop was held in St. Louis to describe the software and distribute code. More than 300 pages of documentation and over 28,000 lines of code were distributed to the participants at this time.

Throughout the process, a number of groups including RSNA, ACR, NEMA, and RISC provided substantial support to the effort. During the week of September 14, 1992, an evaluation and validation session was arranged in Chicago for each of the vendor participants in order to work out all of the many anticipated difficulties. Although a week was set aside for this process, everyone was surprised to find that all of the vendors were successfully communicating using the DICOM protocols during the first day of the trial.

At RSNA '92, a highly successful demonstration took place in a large venue that was the focal point of the *info*RAD exhibit. Most of those who saw and participated in the demonstration recognized that it represented an important step forward in the public recognition of the value and importance of an imaging standard.

The success of the 1992 demonstration provided a foundation for a more elaborate demonstration in 1993 and Mallinckrodt was again asked to develop software, this time with substantially enhanced functionality that incorporated HIS/RIS connectivity. This software was subsequently placed into public domain. Even more ambitious plans are called for in 1994 and 1995, when true interconnectivity among vendors and academic participants at the annual RSNA scientific assembly will be realized throughout the entire meeting.

I am proud of the efforts of the Electronic Radiology Laboratory but am quick to recognize that this is only a very small element of an effort that has been carried forward on a number of fronts for many years by a host of de-

voted individuals and organizations. DICOM has finally reached a high level of acceptance. The public demonstrations have served to prove the feasibility of the process, and industry is now investing seriously in the realization of a method for true intervendor connectivity. Most agree that this long-awaited standard will facilitate the vigorous growth of digital image management, which, in turn, will transform the way we practice radiology in the years ahead.

The Role of ACR and NEMA in Supporting the Standard

Joseph N. Gitlin, DPH

The approval of DICOM 3.0 for publication and the demonstration of implementations as commercially available products at RSNA '94 are important milestones in the continuing development of the standard. These milestones represent the successful accomplishment of the major goals adopted by the American College of Radiology (ACR) and the National Electronics Manufacturers Association (NEMA) when the joint effort was defined in 1983. After more than 10 years of intensive effort by both the ACR, which represents the principal users of imaging equipment, and NEMA, which represents the major suppliers, the network version of the standard is available. It is anticipated that this version will be formally adopted as a national and international standard in 1995, after submittal to the appropriate governing agencies in Japan, Europe, and North America.

The demonstrations of the standard at RSNA '94 will include the public domain implementation developed at the Mallinckrodt Institute of Radiology with support from RSNA, and commercially available interpretations by more than 40 companies that will be linked to RSNAnet at the annual meeting. The large number of products that comply with the standard should facilitate the utilization of digital image management systems and picture archiving and communication systems (PACS) by hospitals and other health care organizations. The demonstration at this time is particularly appropriate in view of the emphasis on advances in medical imaging associated with the 1995 centennial celebration of Roentgen's discovery of x rays.

The impetus for the development of the standard was the recognition of the value of digital imaging devices such as computed tomography (CT) (known as computerized axial tomography in the 1970s) in the diagnosis of a wide variety of diseases and injuries. The immediate clinical acceptance of CT and the availability of other digital imaging modalities such as nuclear medicine, ultrasound, and magnetic resonance imaging generated the perceived need for integrated electronic systems that could accommodate all types of imaging equipment produced by different manufacturers. This, in turn, led to the recognition that a standard was required to ensure effective communication among the imaging devices and related computer equipment.

While the need for an interface standard was long recognized, effective action to create the standard did not occur until 1983, when members of the ACR combined efforts with representatives of manufacturers through the newly formed ACR-NEMA Standards Committee. This committee, through joint action, was extraordinarily effective. In just 2 years, the committee and its working groups created an industry-standard interface originally known as the ACR-NEMA Digital Imaging and Communications in Medicine (DICOM) standard (defined in NEMA publication no. 300-1985). By the RSNA annual meeting in 1987, most manufacturers had included the ACR-NEMA standard in their lists of equipment specifications (1).

The ACR presented the needs and rationale for the effort, while NEMA committed itself to resolve the technical issues that faced the industry. A joint committee composed of radiologists and experts from industry was formed to address the issues of compatibility involved in the interface of various digital imaging modalities. Over the next 2 years, working groups met, shared information, and developed the hardware specifications, defined the data elements needed in a message, and established goals for system performance and function (2).

The ACR-NEMA standard interface allows digital medical images and related information to be communicated between imaging devices, regardless of manufacturer or im-

age format. Development of this interface was believed to be the first step necessary in the development of standards for PACS. Without data exchange, the backbone of digital image communication and storage, other efforts to encourage the development of PACS would fail.

At the first PACS meeting (held in 1982), the problem of acquiring images and related data from different manufacturers' equipment was already apparent. The desire to acquire digital data in a direct manner was strong, but vendors were cautious about revealing how their software worked. The potential users of PACS, namely the radiology community, asked the ACR to help find a solution. Engineering experts among the manufacturers also began to realize that little would be gained by keeping image formats proprietary. The result was the formation of the ACR-NEMA Digital Imaging and Communications Standards Committee early in 1983 (3).

After 2 years of work, the first version of the standard, ACR-NEMA 300-1985 (also called ACR-NEMA version 1.0), was published and distributed at the RSNA annual meeting in 1985. As with many first versions, errors were found, and improved ways of doing things were suggested. In response, the committee began working on changes to improve the standard. In 1988, ACR-NEMA 300-1988 (or ACR-NEMA version 2) was published. It used substantially the same hardware specification as version 1 but added new data elements and fixed a number of errors and inconsistencies.

By 1988, many users recognized that an efficient interface between imaging devices and a network was required. While this could be done with version 2, the standard lacked the parts necessary for robust network communication, and a solution to these problems meant that major changes would have to be made to the standard with the constraint of retaining compatibility with earlier versions.

The ACR-NEMA DICOM standard has gained recognition by manufacturers and users as a significant factor in the future of medical imaging. It must be remembered that because the standard is not mandatory, its implementation

by equipment suppliers is optional. Support for the standard has grown with migration from the "black-box" to an integrated interface (4). The standard is seen as a dynamic development, being changed and improved in response to the needs of the medical community with the support of the manufacturers. A goal of the committee is to make future versions of the standard compatible with previous versions and, whenever possible, develop new versions that can be "understood" by existing implementations.

It is anticipated that ACR and NEMA will continue to support further development of the standard and that collaboration with other medical disciplines and international agencies will enhance its utility around the world. Although much remains to be done, a great deal of credit is due the individuals and organizations that have contributed to the progress to date. Roentgen's centennial year should see formal adoption of version 3.0 and the establishment of an international "consortium" that will have the responsibility and resources to continue the dynamic process of developing future versions of the standard. These efforts often seem far removed from the delivery of care to patients, but if medical imaging technology is to continue its contributions to cost-effective diagnosis and treatment, an evolving standard is an essential component.

References

1. Lodwick GS. PACS and the ACR-NEMA digital image communications standards. Administrative Radiol, May 1988; 7–10.
2. Wang Y, Best DE, Hoffman JG, et al. ACR-NEMA digital imaging and communication standards: minimum requirements. Radiology 1988; 166:529–532.
3. Horii SC. The ACR-NEMA standards. Administrative Radiol, Feb 1990; 69–75.
4. Spilker C. The ACR-NEMA digital imaging and communications standard: a non-technical description. J Digit Imaging 1989; 2:127–131.

CHAPTER 2
History and Essentials of DICOM

Historic Development and Essential Features of the DICOM 3.0 Standard

Robert Hindel, PhD

The DICOM 3.0 standard evolved from earlier versions called ACR-NEMA standards version 1.0 (1985) and version 2.0 (1988) (1,2). The essential demand for a digital imaging standard arose in the early 1980s from the frustration of ACR representatives with the inaccessibility of digital image data produced by CT scanners and MR imagers. These data were stored on magnetic tapes and flexible disks (floppies) but could not readily be deciphered by the customers. The single most significant demand from ACR was that NEMA, as industry representative, should cooperate in forming a standards committee charged with addressing this issue. Three working groups (WGs) were formed, each reporting to the ACR-NEMA standards committee, which was headed jointly by an ACR representative and a NEMA representative. The original WGs were

WG I	Hardware and Protocols
WG II	Data Groups
WG III	System Performance Specifications

New WGs are

WG IV	Data Compression
WG V	Exchange Media
WG VI	Validation (and Upgrades)
WG VII	Multidimensional Data
WG VIII	HIS/RIS/PACS Interface

Other new WGs have since been proposed.

Now, 9 years later, the definition of images is still the most important information, although it occupies only a fraction of the bulk contained in the 10 parts of DICOM 3.0 Standard (3). These are

Part 1	Introduction and Overview
Part 2	Conformance
Part 3	Information Object Definitions
Part 4	Service Class Specifications
Part 5	Data Structure and Semantics
Part 6	Data Dictionary
Part 7	Message Exchange
Part 8	Network Communication
Part 9	Point-to-Point Communication
Part 10	Media Storage and File Format

Diagnostic images, particularly series of CT, MR, and ultrasound images, may be 100 MByte (100 million bytes) or larger. Sophisticated technology is needed in order to fetch these images fast from storage and present them conveniently to the radiologist. A fast network is needed if these images are remotely stored. By contrast, all other clinical and demographic information can be expressed by less than 0.1% of the data quantity needed for images. Robust, reliable, and affordable technology exists that can handle such quantities. Furthermore, well-established radiology information systems (RIS) and hospital information systems (HIS) exist and provide information and department management functions.

In response to the published version 2.0 of the ACR-NEMA standard, users requested a network version. It also became evident that medical informatics should be addressed on a broader basis. The developments in Europe initiated by the Comité Européen de Normalisation (CEN) through its Technical Committee 251 (TC 251) required a matching design. A crucial requirement was adherence to language and structure of OSI. (More information about TC 251 is available in Appendix C.)

In 1991, NEMA joined HISPP, the ANSI Healthcare Information Standards Planning Panel, which coordinates efforts toward a comprehensive healthcare informatics standard in the United States. (More information on this topic is available in Appendix B.)

Therefore, the ACR-NEMA standard, version 2.0 was

rewritten in order to become conformant with ISO and OSI.

THE CONCEPT OF AN OPEN SYSTEM

The DICOM standard is patterned after OSI, the Open System Interconnection of ISO. The key feature of OSI is **communication between heterogeneous systems.** It was developed as a generalized model based on the experience with ARPANET and CYCLADES (4). "Openness" is established when participating parties agree on a communication protocol. The "message" that is transmitted between the communicating partners ("nodes") is expressed in a specified form. The DICOM standard specifies this form through the tranfer syntax that defines the coding of the information. The message itself is accompanied by instruction elements appropriate to the communication channel (for instance, which communication "stack" will be used).

A nontechnical parallel would be a communication between two mathematicians with no common conventional language, in which one asks a question by means of symbols, and the other replies by means of symbols. They would use mathematical coding as a common language. Alternatively, they could each find a translator who speaks a common conventional language. This would require double translation in each direction; faulty "coding" (misunderstandings) would probably occur.

Aside from the enormous amount of detail and complexity of the OSI standard, the essential feature of the standard is the transportable message in well-defined form, the capability of the sending node to generate this message, and the corresponding capability of the receiving node to decipher or parse this message. The sending and receiving nodes need not use the same operating system or the same application program. They can be, and in many cases will be, heterogeneous.

Internet, which evolved from ARPANET, is an example of such an open communication system (5). According to some sources, it connects more than 2 million computers and ac-

commodates more than 15 million users. It offers greater functionality than DICOM but simpler coding.

References

1. Spilker C. The ACR-NEMA digital imaging and communication standard: a non-technical description. J Digit Imaging, August 1989; 1:127–131.
2. Horii SC, Hill DG, Blume HR, et al. An update on ACR-NEMA standard activity. J Digit Imaging, August 1990; 3:146–151.
3. DICOM 3.0 Digital image and communication standard, 1993.
4. Zimmermann H. OSI reference model: the ISO model of architecture for open systems interconnection. IEEE Tran Comm 1980; 28:425–432.
5. Krol E. The whole internet catalog. Sebastopol, Calif: O'Reilly & Associates, 1992.

Designing DICOM Conformance

Fred Prior, PhD

1. INTRODUCTION

A standard is an agreement that establishes a framework within which to solve a class of problems. It is meant to facilitate consistent implementations by building an abstract model of a class of solutions. A standard is not an implementation specification. It cannot guarantee interoperability of implementations.

The DICOM standard includes a broad selection of services and a variety of options. Any implementation will logically select a subset of functions and optional elements. For interoperability it is essential that these choices be made consistently. The standard provides a mandatory mechanism whereby implementors can define precisely the subset of DICOM features and functions that comprise a particular implementation.

NEMA publication PS 3.2-19931 (1) specifies that all implementations must be accompanied by a properly structured Conformance Statement. A Conformance Statement is a formal compilation of the exact set of DICOM functions, services, and options that are included in a particular implementation. The Conformance Statement must indicate how the implementation meets the conformance re-

quirements specified in all other parts of the DICOM standard.

Conformance to a standard means compliance to the requirements of the standard. Conformance does not mean validation. Conformance does not imply a mandate for a particular implementation. The purpose of a Conformance Statement is to allow a user to determine which optional components of the DICOM standard are supported by a particular implementation and what extensions or specializations an implementation adds. By comparing the Conformance Statements from two implementations, a knowledgeable user should be able to determine whether or not interoperability is possible. If the Conformance Statements are complimentary, and the vendor's implementations are adequately and accurately described by these statements, the probability of interoperability is greatly increased.

How should a user specify DICOM conformance? History has shown that simply writing a request for proposal or purchase agreement requiring "ACR-NEMA" or "DICOM" is not sufficient. The user community needs to understand the conformance specification process and to clearly articulate DICOM conformance requirements (2). It is also incumbent upon the user community to police the market and call into question marketing claims that are not backed by a properly constructed conformance statement. The Conformance Statement must become a key customer requirement levied on all vendors.

It has been observed by several implementors that the best way to grasp the requirements of the DICOM standard is to carefully study the conformance document (1). This is not surprising, since the goal of any implementation is to solve a problem in a way that conforms to the requirements of the standard. The following sections will explore the structure of a DICOM Conformance Statement and how it may be used as a road map to the standard.

2. STRUCTURE OF A CONFORMANCE STATEMENT

NEMA publication PS 3.2-1993 defines the requirements for creating a Conformance Statement. Annex A of this docu-

ment is a detailed outline of an arbitrary Conformance Statement. Annex B provides an example of a Conformance Statement based on two fictional applications: DIS and DAT. Van Syckle et al (3) describe a more concrete example based on an actual implementation. It is crucial to note that PS 3.2 only specifies requirements for the creation of a Conformance Statement. The actual conformance requirements to which implementations must comply are specified in the remaining parts of the standard (NEMA publications: PS 3.3 - PS 3.10).

A DICOM Conformance Statement that describes an actual implementation does not have to exactly follow the format defined in PS 3.2 Annex A. It does, however, have to include a comprehensive description of the implementation. Figure 1 is a pseudocode representation of the Conformance Statement generation algorithm defined by Annex A. The reader will note several conditional statements and reasonably complex looping structures (indicated by "For" and "End For").

The initial section of a Conformance Statement must identify the domain of application of the implementation. This is done by clearly stating the problem set being addressed (e.g., transferring images from a CT scanner to a storage device) and by a data-flow diagram that relates the implemented functionality to real-world activities. At this highest level of abstraction, the Conformance Statement deals with activities and events in the real world and identifies application entities (AEs) that implement DICOM functions relevant to the identified activities.

A DICOM AE is a named package of DICOM services that may be separately addressed on a network. Most likely, an AE is a software process running on a host processor. An AE uses DICOM services to implement a subset of the application layer functionality defined by the DICOM standard. Any DICOM implementation will comprise one or more AEs. The goal of a Conformance Statement is to completely specify the functionality and constituent components of these AEs. As illustrated by Figure 1, the bulk of a Conformance Statement is taken up by AE specifications.

An application data-flow diagram is an important tool to graphically illustrate the domain of interest of the implementation, how the implementation is partitioned into AEs and how real-world activities relate to the supported DICOM functions. Figure 2 is an example of a data-flow diagram of the type proposed in Annex A. Although initially created as part of a user conformance document rather than a conformance statement, it illustrates the basic concepts and content of such a diagram. The diagram represents a generic modality interface that supports a means to communicate (*a*) patient and study identification information from an information system (HIS/RIS/PACS) to an imaging modality and (*b*) images and study component information from the modality back to storage and information management systems.

By DICOM convention, an application data-flow diagram uses rectangles to illustrate AEs and circles for real-world activities. The model is divided into two segments: internal to the implementation environment being described and external. Single-headed arrows are used to indicate the direction of association establishment (the arrowhead points away from the association initiator) and double-headed arrows to indicate the relationship between internal triggering events and actions across the DICOM interface boundary. In the example in Figure 2, two AEs have been identified: a study management (SM) AE and an image management (IM) AE. The SM AE receives association requests from a DICOM service class provider wishing to communicate information about a study scheduled event (one of the event types specified in PS 3.4 as part of the Detached Study Management Service Class specification). The SM AE initiates associations to a DICOM service class providers to get patient information, create study components, and update study component information. The IM AE initiates associations to store images to a service class provider of the appropriate storage service object pair (SOP) class.

Once the functional scope of the conformance statement has been articulated and a set of AEs identified, focus shifts

```
AE Specifications
For each AE
        If this AE initiates Associations Specify Association establishment policies
        For each Real-World Activity that results in Association initiation
        Specify associated Real-World Activity
                        Specify proposed Presentation Contexts
                        For each Presentation Context
                                Specify SOP Specific Conformance
                        End For
                End For
        End If

        If this AE accepts Associations
                Specify Association acceptance Policies
                For each Real-World Activity that results in Association acceptance
                Specify associated Real-World Activity
                        Specify acceptable Presentation Contexts
                        For each Presentation Context
                                Specify SOP Specific Conformance
                        End For
                        Specify Presentation Context acceptance criteria
                Specify Transfer Syntax selection policies
    End For
      End If
End For

Communication Profiles

  For each supported OSI stack
    Specify International Standardized Profile (ISP)
  End For
  If the TCP/IP Stack is supported
    Specify TCP/IP support
  End If
  If Point-to-Point Stack is supported
    Specify Point-to-Point support
  End If
  If the product claiming conformance is a tool kit
    Specify an Application Programming Interface
  End If
  Specify physical media support

Extensions/Specializations/Privatizations

  If any extensions to the standard were referenced in AE Specifications
                For each Standard Extended/Specialized/Private SOP
                        Specify the Standard Extended/Specialized/Private SOP
                End For
  End If
  If any Private Transfer Syntaxes were referenced in AE Specifications
      For each Private Transfer Syntax
                Specify the Private Transfer Syntax
      End For
  End If

Configuration
Support of Extended Character Sets
```

Figure 1. How to construct a DICOM Conformance Statement with an implementation model.

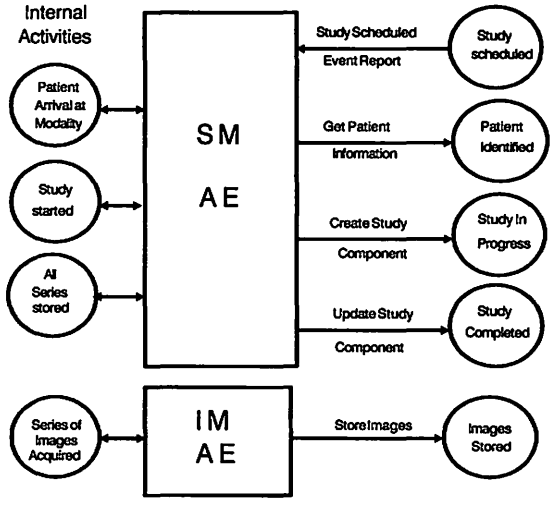

Figure 2. Example application data – flow diagram.

to a much lower level of abstraction. The behavior of each AE must be described in detail.

3. APPLICATION ENTITY SPECIFICATIONS

A complete specification must be provided for each AE encompassed by the Conformance Statement. The specification must enumerate the functions performed by the AE and the DICOM services that are used. A summary list of SOP classes to which the AE conforms should be provided.

An SOP class is the atomic unit of conformance. A SOP class UID uniquely specifies a set of DICOM message service elements (DIMSE) and a DICOM information object definition (IOD) plus additional application specific semantics (as defined in the service class specification to which the SOP class belongs). The SOP class UID plays a second role in DICOM. Because they each identify a well-defined unit of DICOM functionality, SOP class UIDs are used as the Abstract syntax name component of a presentation context. It is, therefore, the SOP class that is negotiated during Association establishment.

For each real world activity identified in the data-flow diagram (Fig 2), the AE specification must indicate whether

Presentation Context Table

Abstract Syntax		Transfer Syntax		Rol e	Ext. Neg.
Name	UID	Name List	UID List		
CT Image Storage	1.2.840. 100085.1.4 1.1.2	DICOM impl. VV Lit. End.	1.2.840. 10008.1.2 1.2.840.10008.1.2.2	SCU	none
		DICOM expl. VR Big End.			
CRA Image Storage	1.2.840.10008.5.1.4 1.1.2	DICOM impl. VR Lit. End	1.2.840.1008.1.2	SCU	none
		DICOM expl. VR Big End.			

Figure 3. Example of a presentation context table.

the AE initiates or accepts associations and describe any implementation specific behaviors. For each association it is necessary to identify the set of acceptable presentation contexts. A table such as the example illustrated in Figure 3 should be included. Such tables summarize a great deal of information, including acceptable abstract and transfer syntaxes, whether the AE acts as a service class user (SCU) or service class provider (SCP) of the indicated SOP class, and whether SOP specific extended negotiation is supported.

It the AE accepts associations, the Conformance Statement must indicate the criteria and priority for choosing presentation contexts when multiple are supported. Similarly, if the AE can support multiple transfer syntaxes within a given presentation context, the policies and priorities governing syntax selection must be specified.

4. COMMUNICATION PROFILES AND CONFIGURATION

DICOM is a communication standard. Logically, one would expect the bulk of the standard to be devoted to the specification of communication protocols at each of the seven layers of the ISO Open Systems Interconnect (OSI) reference model 4. In fact, the DICOM standard deals almost exclusively with the seventh (application) layer of the OSI model. Only NEMA publications PS 3.8 and PS 3.9 actually address the lower six layers.

DICOM applications are defined to function over three distinct classes of lower-layer protocol stacks: ISO, TCP/IP, and the DICOM point-to-point protocol. A conforming implementation may choose to support one or more of these protocols. In all cases, significant details of the chosen stack must be communicated. For example, DICOM does not specify a specific ISO international standard profile (ISP) but rather permits the implementor to select from several possible known ISPs (e.g., US GOSIP [7]). Clearly it is important for interoperability for this selection to be indicated in the Conformance Statement.

The DICOM standard permits a number of media access layer protocols and physical media. The Conformance statement must indicate which protocols (e.g., FDDI, Ethernet, orISDN) are supported and over which media (fiber, coaxial cable, twisted pair, etc.). Each of the possible media requires specific transceivers and connectors. Anyone who wishes to determine the interoperability of two implementations needs a clear understanding of the supported protocols and physical media options they support. DICOM over FDDI and DICOM over primary-rate ISDN are both valid implementations but are not directly interoperable.

Each implementation will logically include a number of configurable parameters. At a minimum, a mechanism for mapping AE titles (logical addresses) into presentation addresses (or in the TCP/IP world, IP addresses) must be provided. The standard requires this but does not specify the mechanism. It is important to define in a Conformance Statement how this task is accomplished. Similarly, if the

implementation includes an SCP that invokes the DIMSE N-Event-Report service, it is necessary to specify the mechanism the AE will use to determine the list of AE Titles to which event reports are to be sent. Finally, permitted values of configurable parameters such as time-out thresholds should be specified.

5. EXTENDING THE STANDARD

The DICOM standard includes provisions for an implementor to extend the currently defined functionality of the standard. These provisions were included to permit experimentation with new techniques and even new imaging modalities that are not yet covered by the standard. If an implementation employs one of the extension techniques, and the implementor wishes to make the extensions public, the Conformance Statement must include a complete specification of the extension.

Three basic mechanisms are provided to extend the DICOM standard: standard extended SOP classes, specialized SOP classes and private SOP classes. A standard extended SOP class is a slight variation on one of the SOP classes defined in PS 3.4. In must meet all of the requirements for the standard SOP class upon which it is based and only include additional optional (type 3) attributes. These attributes may be either public attributes defined in the DICOM data dictionary or private attributes defined by the implementor (equivalent to ACR-NEMA version 2.0 "shadow elements") (8). A standard extended SOP class uses the same unique identifier (SOP class UID) as the standard SOP class upon which it is based. A specialized SOP class is also based on a standard SOP but it may contain additional attributes (either public or private) that are mandatory. Because this introduces new semantics, a specialized SOP class must be identified with a user-specified SOP class UID. A Private SOP class introduces completely new functionality and is not necessarily based on any existing DICOM-defined SOP. It may contain public and private attributes. The implementor is only restricted in that no new DIMSE services may be utilized in a private SOP class.

If specialized or private SOP classes are defined and the implementor wishes to make these private extensions of the standard publicly available (so that others might support them), the Conformance Statement must contain a detailed definition of the SOP class. In short, the implementor is required to replicate the relevant sections of NEMA publications PS 3.3, PS3.4, and PS 3.6 in the Conformance Statement.

6. CONCLUSIONS

A properly structured Conformance Statement must accompany all DICOM products. It is incumbent on the manufacturer to assure that published Conformance Statements are valid (i.e., that they match the associated implementation). This is a vital requirement that must be met by vendors if the DICOM standard is to make a positive impact on the medical imaging market. The responsibility for enforcement lies with the user community. If a vendor says that its product supports DICOM, the user community must universally respond: "Show me your Conformance Statement!" Without a Conformance Statement, a system does *not* comply with the standard.

References

1. American College of Radiology, National Electrical Manufacturers Association. Digital imaging and communications in medicine (DICOM): conformance. Washington, DC: NEMA publication PS 3.2-1993, 1993.
2. Prior FW. Specifying DICOM compliance for modality interfaces. RadioGraphics 1993; 13:1381–1388.
3. Van Syckle DE, Sipple-Schmidt t, Parisot CR. Buying imaging products with DICOM interface-made easy. In: Boehme JM, Rowberg AH, Wolfman NT, eds. SCAR '94 computer applications to assist radiology. Carlsbad, Calif: Symposia Foundation, 1994; 529–536.
4. International Standards Organization. ISO 7498. Information processing systems: open systems interconnection — basic reference model. New York, NY: American National Standards Institute, 1984.
5. American College of Radiology, National Electronics Manufacturers Association. Digital imaging and communications in medicine

(DICOM): network communication support for message exchange. Washington, DC: NEMA publication PS 3.8-1992, 1992.
6. American College of Radiology, National Electronics Manufacturers Association. Digital Imaging and communications in medicine (DICOM): point-to-point communication support for message exchange. Washington, DC: NEMA publication PS 3.9-1993, 1993.
7. National Bureau of Standards. Government open systems interconnection profile (GOSIP). Federal Information processing standards publication 146. Springfield, Va: National Technical Information Service, 1988.
8. American College of Radiology, National Electronics Manufacturers Association. ACR-NEMA digital imaging and communications standard 300-1988. Washington, D.C.: National Electronics Manufacturers Association, 1989.

The Open Communication of Image and Related Data with the DICOM Standard

Charles Parisot

SUMMARY

The DICOM standard has been approved by ACR and NEMA in October 1993 and is being adopted as a European standard called MEDICOM. It represents a major breakthrough in the communication of medical images in an electronic form. DICOM has been designed to take advantage of the increasing use of computer networks in health care. This article focuses on the network communication as well as introduces the extension of DICOM for media interchange that is to be approved late in 1994.

1. DICOM FOR OPEN NETWORKING

Figure 1 presents a graphical overview of the three application networking capabilities supported by DICOM (NEMA PS3-1 through NEMA PS3-8):

1. Network Image Transfer
2. Print Management
3. Imaging Study Management

Various medical imaging applications may use these three networking capabilities, which in turn are supported by lower layers of general-purpose networking technology. DICOM identifies a clear and generic boundary, shown as a

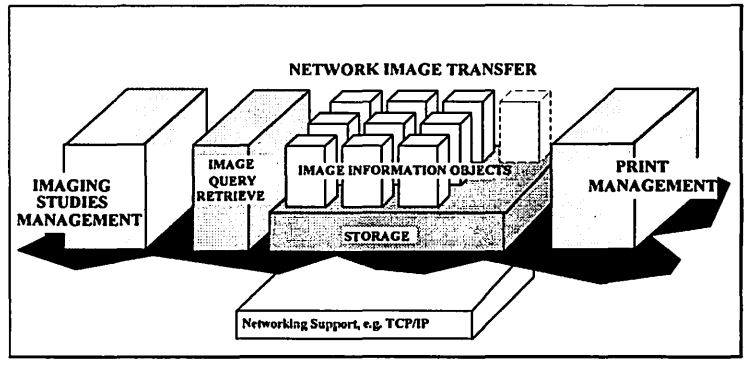

Figure 1. The Three Dimensions of Networking with DICOM

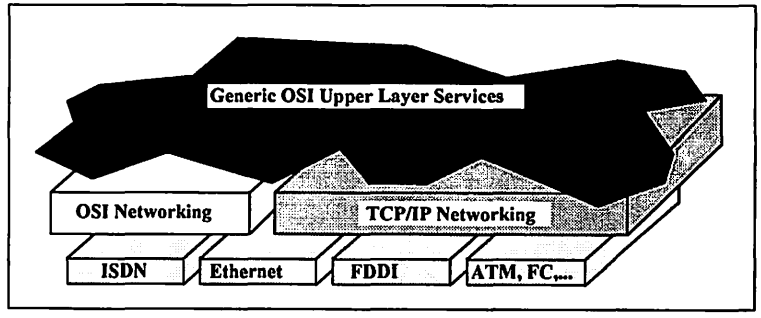

Figure 2. The elements used by DICOM for networking communication support.

black plane in Figure 1, to provide maximum independence of the imaging networking capabilities from the technologies used for building logical and physical networks (e.g., transport and routing protocols, physical network interfaces, and cables). The manner in which the DICOM networking services are supported by generally available network technologies will be discussed first, followed by the DICOM networking services themselves.

Figure 2 depicts the functional components that DICOM has standardized below this generic boundary (called the generic OSI upper-layer services). These components are not specific to medical imaging but are general-purpose standards commonly available from the computer and telecommunication industry. They are specified in part 8 (NEMA PS3-8) of the DICOM standard.

Part 8 of DICOM allows two choices of functionally equivalent networking standards to ensure the reliable and

efficient transfer of the DICOM messages. The first is based on the Transport Control Protocol/Internetwork Protocol, or TCP/IP. It results from a standardization effort by the U.S. Department of Defense in the early 1980s and is broadly used by the computer industry today. The vast majority of DICOM implementations available on the market today have selected this approach. The second, Open System Interconnection (OSI), is based on a set of ISO standards. Even though OSI is the result of a massive standardization effort performed in the late 1980s, it is in limited use at the present time.

At the physical networking level, DICOM supports a large variety of cost-effective local area (LAN) and wide area network (WAN) technologies. (Only a few are shown in Figure 2.). No restriction of choice is imposed by DICOM, because a logical seamless network can be built by combining the use of several of these types of physical networks. This flexibility allows the design of cost-effective configurations to satisfy virtually the needs of any health care institution. Most implementations of DICOM have selected Ethernet.

Image Transfer

The image transfer services of DICOM form the most broadly implemented part of the standard. These application-level services rely on the above networking protocols. They are specified mainly by DICOM part 4 (PS3-4). Two basic networking capabilities, called DICOM service classes, are defined:

1. The storage service class
2. The query/retrieve service class

When implementing the storage service class, a sending DICOM application can send ("push") an image to a receiving application. If repeated for every image of a study, an entire study may be pushed across the network. With this basic service class, the sender does not have the ability to request that a certain usage or processing be performed

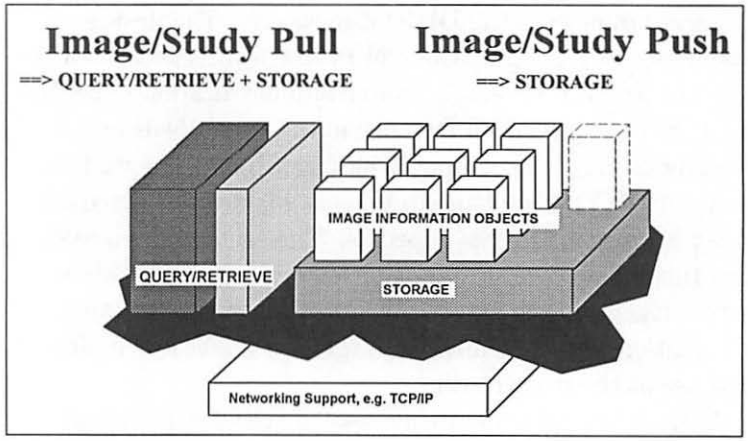

Figure 3. The structure of the DICOM image transfer service classes.

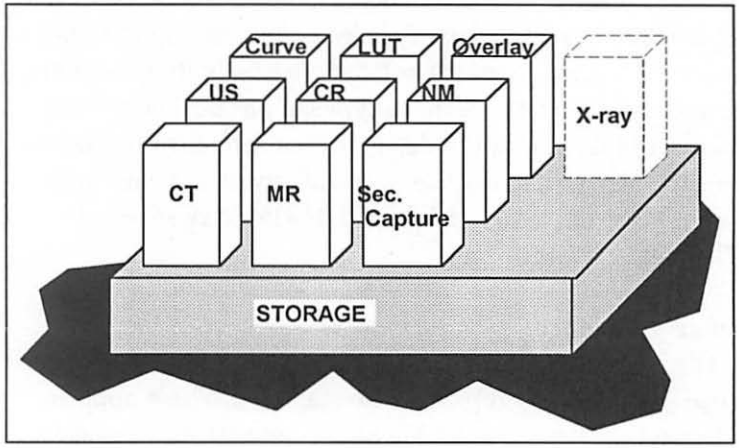

Figure 4. The DICOM image information objects and the storage service class.

with the image. It is the receiver's decision. The storage service class in DICOM part 4 specifies transfer operations common to all types of images (called information objects) irrespective of the modality. In part 3 of DICOM, a wide choice of image information objects is defined to support a wide range of imaging modalities.

When implementing the query/retrieve service class, one DICOM application has the ability to search a remote node's database for patient records, studies, series of images, and even individual images. Once selected, the corresponding image or images may be requested or retrieved.

The storage service class is used to actually transfer the requested image(s). The combined used of the query/retrieve and storage service classes provides the ability to retrieve ("pull") a set of images from a remote node.

The DICOM storage service class defines a large choice of modality images. These are presented in Figure 4. These modality image objects are specified in DICOM part 3 (PS3-3). Five modalities are addressed: Computed tomography (CT), magnetic resonance (MR) imaging, computed radiography (CR), ultrasound (US), and nuclear medicine (NM). In addition, digitizers, frame grabbers, and soft screen capture are addressed by the secondary capture (SC) and standalone overlay (e.g., text screen) information objects. Finally, look-up tables of different type are supported by modality or VOI LUT objects.

The support of radiographic images (angiographic or cardiovascular as well as fluoroscopic images) is expected to be approved late in 1994 as two supplements to the DICOM standard.

Such information objects include not only the definition of the pixel data structure but also the related information that ensures appropriate use of the image pixel data. It provides a precise definition for each attribute of an image. The effective interoperability achieved by DICOM is largely based on this highly structured specification.

DICOM Conformance

The same figure that illustrates the DICOM networking capabilities may be used to introduce the role of a DICOM Conformance Statement (Fig 5). A DICOM Conformance Statement identifies which DICOM building blocks are implemented in a product. In the example below, the implementation claims to support query/ retrieve and the storage of MR images with TCP/IP over Ethernet.

DICOM requires that every implementation claiming conformance to DICOM provide a Conformance Statement. By comparing the Conformance Statements side by side, one will be able to assess the communication abilities of two implementations.

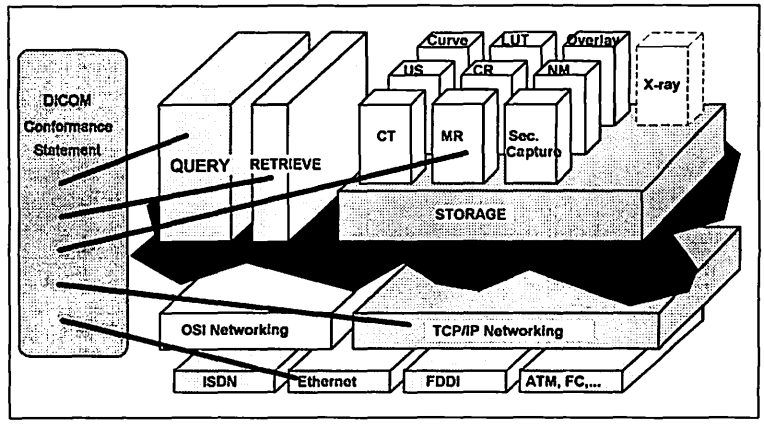

Figure 5. A DICOM Conformance Statement states which building is implemented in a product.

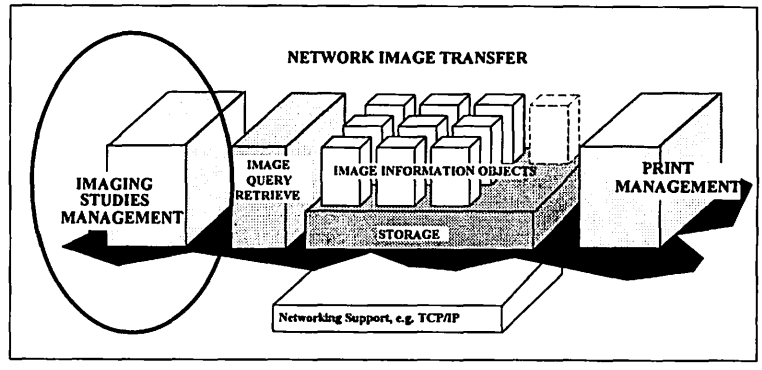

Figure 6. DICOM imaging study management.

Network Imaging Study Management

The second major capability provided by DICOM is the exchange of information that allows the management of imaging studies. This building block (Fig 6) may coexist and be integrated with the exchange of images as described in the previous section.

This capability is often called the "HIS/RIS-PACS interface." It is based on an information model that defines the relationship between the management of information and images. This feature is key for providing productivity improvements within the hospital. It includes three service classes defined in DICOM part 4:

1. The study management service class provides a means to obtain study information (before and after acquisi-

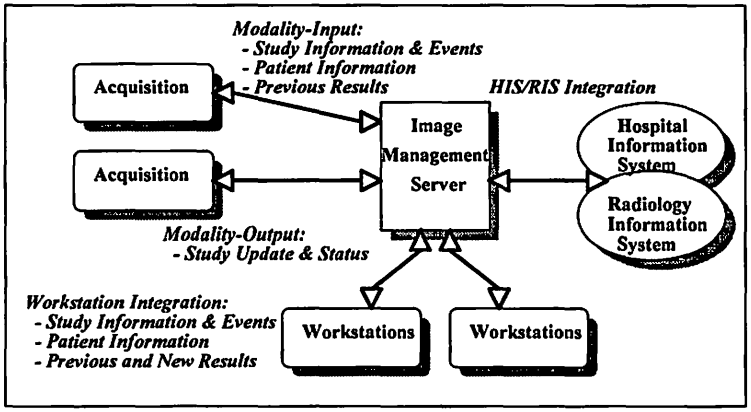

Figure 7. Example of use of the imaging study management service classes.

tion). It allows the tracking of the study status and its image content by avoiding reentry of information and associated potential errors.

2. The patient management service class provides a means to obtain patient demographics that, like the study management service class, avoids reentry. It enables performance optimization such as the prefetching of images.
3. The results management service class provides the means to obtain result information and corresponding interpretations both for prior studies as well as for the electronic management of results (review and approval of reports).

These service classes will be used by acquisition systems and workstations for the building of an integrated image management environment. A typical example of how the standard may be used is depicted in Figure 7.

Network Print Management

The third major networking capability provided by DICOM is the ability to print images on a networked hardcopy device (e.g., a laser camera). This building block (Fig 8) is called the print management service class. It is specified in DICOM part 4 (NEMA PS3-4).

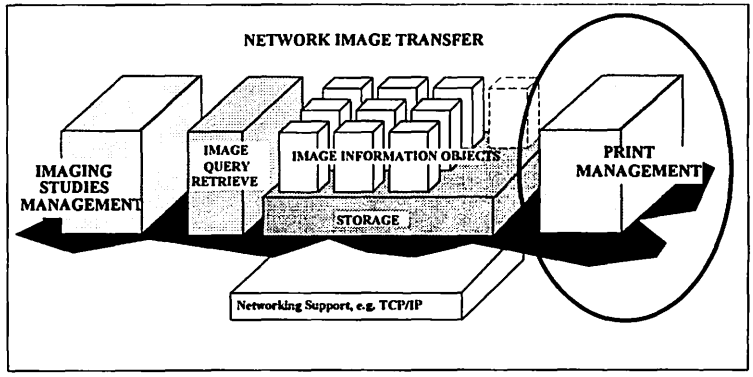

Figure 8. The print management building block of DICOM.

This service class is structured to support basic print management (either gray-scale or color). It provides:

- The support of preformatted or camera-ready images,
- The control of film layout (film format, magnification, number of copies, etc.), and
- The management of the printing device (magazine low/empty, out-of-service, etc.).

This basic print management service may be extended by one or more of the following options:

- Print Job management (e.g., being notified when the film is available from the processor);
- Print by image reference (the printer is provided a full resolution image); and
- Annotation and overlay (the printer may be instructed to place a textual banner on a film).

A new part 13 of DICOM was approved in September 1994 to support a non-network interface of printers. This point-to-point extension has been designed to use the type of physical interfaces commonly used by the hard-copy industry today (a parallel interface for pixel input and an asynchronous link for DICOM print management control).

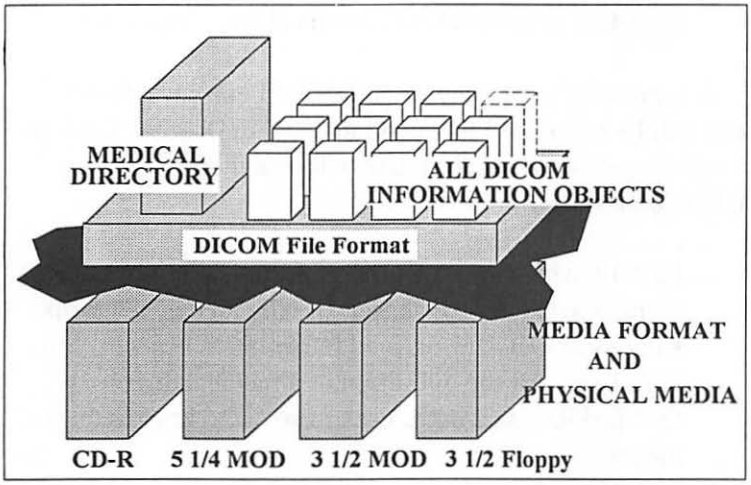

Figure 9. DICOM media storage architecture.

2. DICOM MEDIA STORAGE

Late in 1994, a set of supplements to DICOM "networking" is expected to be submitted for final approval. These supplements provide a comprehensive approach to the storage of images and related information on media of various types (disks, tapes, etc.). These supplements extend DICOM by introducing three new parts to the standard.

The DICOM approach to media storage is based on an architecture similar to the one successfully used in the networking arena (Fig 9). It is based on a number of fundamental principles:

1. A number of industry standard media storage technologies (magnetic disks, optical disks, tapes, etc.) are available, and none should be excluded a priori . Different application contexts are likely to require that more than one technology be supported by DICOM.
2. The evolution of physical storage media as well as corresponding media formats (e.g., file systems) is not primarily driven by the medical imaging industry, but rather by the computer and multimedia industry. DICOM should not invent new choices but rather select the most appropriate ones.
3. The information objects used are identical to the ones used in the network. This is key for facilitating the in-

tegration of network and media storage exchange.

A number of supplements to DICOM are now "frozen" and will be submitted for final balloting in October 1994. As a consequence, three new parts will be added to the DICOM standard:

1. Part 10, which specifies the general DICOM media storage architecture as well the file format to encapsulate any DICOM-defined information object. With Part 10 comes the definition of a medical directory that facilitates direct access to selected images on the media.
2. Part 12, which reference industry specifications for the Physical Media and Media formatting file systems. The first version is expected to include five types of media: CD-ROM, 5¼ magneto-optical disk (MOD) (650 Mbyte), 5¼ MOD (1.3 Gbyte), 3¼ MOD (128 Mbyte), and the 3½-inch DOS floppy disk.
3. Part 11, which defines application-specific profiles. A profile is a simple means for users and vendors to specify a selection of physical media among those in part 12 and of information objects among those defined by DICOM part 3.

CONCLUSION

This brief overview of the content of the DICOM standard and of the supplements that are to be finalized late in 1994 should demonstrate the breath of applicability of the standard in creating open image management systems.

CHAPTER 3
Demonstrations of DICOM

The *info*RAD Demonstrations

Robert Hindel, PhD 39

In January 1992, the MedPacs section of NEMA formed an ad hoc committee charged with developing specifications for an *info*RAD demonstration of the evolving DICOM 3.0 standard. Such demonstration was seen as a logical expansion of the 1990 demonstration of the ACR-NEMA point-to-point operation at the Georgetown University hospital (1).

It was also decided that such an *info*RAD demonstration should introduce the network communication specified in part 8 of the DICOM standard. Subsequent meetings resulted in the decision to specify performance for a 1993 *info*RAD demonstration and also to demonstrate a limited version in 1992. It was furthermore decided that an academic institution should be funded to develop prototype software for a central test node (CTN). The DICOM standard does not prescribe or require such a CTN but specifies an open network on which all participating nodes can communicate directly. The CTN, however, was seen as a test suite for various implementations and an efficient method of assuring compatibility. Since an offer by the Electronic Communications Committee existed, it was decided to ask RSNA to manage the demonstrations within the *info*RAD exhibit. On April 13, 1992, RSNA invited 12 institutions to generate DICOM software for a CTN (Table 1).

The functionality of the 1992 demonstration was deliberately limited:

1. Only two of the commands ("services") were implemented (STORE and ECHO). These two sufficed, however, to demonstrate transmission of test images between CTN and demonstration prototype nodes (DPNs).

Table 1

Name of institution	Submit	Elected
Bowman Gray		
Georgetown U.		
HUP	X	
Johns Hopkins		
Mallinckrodt	X	X
Mass General		
Shands U (Fl)		
UCLA		
UCSF	X	
UNC		
UPitt		
UWA Seattle		

2. Test images of clinical significance were supplied by academic institutions.
3. Ethernet was chosen but modified for faster response. The logical CTN performance was physically duplicated by eight CTNs so that only three DPNs had to share one (physical) CTN.
4. The DPNs were exhibited as "works in progress" and not as salable products.

They were not connected to image-generating equipment of the respective company.

On July 15, 1992, the Electronic Radiology Laboratory (ERL) of Mallinckrodt Institute of Radiology, under G. J. Blaine, DSc, conducted a workshop on the CTN prototype software implementation. The software was made available in computer-readable form as well as paper documentation to all participants.

On September 15, 1992, RSNA organized a test in Chicago that demonstrated on the first day that all participants could successfully communicate with the assigned CTNs.

As Table 2 shows, 20 commercial companies participated

Table 2

Company	1992 Demo	1993 Demo	DICOMnet 1993	RSNAnet 1993
AAAI		X		
Acuson		X		
ADAC	X	X		X
AGFA	X	X	X	X
ALI	X			
ATL		X		
Cemax	X	X	X	X
Dupont	X	X		
Fischer	X			
GE	X	X	X	X
IBM	X			
ICON	X	X	X	X
ISG	X			
Kodak	X	X		
Konica		X	X	
Loral		X	X	
Merge	X	X		X
Mitra		X	X	X
MMM	X			
Olicon	X			
ROCS	X			
Philips	X	X	X	
Picker	X	X	X	X
Siemens		X	X	
Star		X		
Toshiba	X			
Virt. Imaging	X			
Vortech	X	X		

in the 1992 demonstration.

The DICOM demonstration at the RSNA 1993 meeting was an activity of the RSNA Electronic Communications

Committee. With written specifications from NEMA, RSNA managed the project, designed and installed the exhibit and its electronic network, and funded the development of prototype CTN software through contract with the ERL of the Mallinckrodt Institute of Radiology.

The 1993 *info*RAD demonstration significantly extended the functionality.

- HIS and PACS services (e.g., patient admission notification, order entry notification, study completion notification, study results reporting, and various queries on the patient, modality, study and series level) were added.
- Image transfer from all "public" image stores, not only the assigned ones.

These public stores also contained images generated by a particular vendor.

- A second CTN design generated by a European consortium was incorporated.
- Ethernet and FDDI links were offered for transmission of images and other information between the *info*RAD exhibit and the main exhibit floor.

Table 2 lists 19 companies that participated in the 1993 *info*RAD demonstration; 10 also participated in the 1992 demonstration and 10 companies used extension links to their respective booths on the main exhibit floor via the DICOMnet. In addition, eight companies transmitted images on the RSNAnet.

The two *info*RAD demonstrations were successful because of the enthusiastic cooperation between a professional society (Radiological Society of North America), an academic institute (Mallinckrodt Institute of Radiology), and a trade association (NEMA). None of them could have succeeded alone with this ambitious project. It should also be mentioned that ACR has contributed greatly to the de-

velopment of the DICOM standard and its demonstrations in 1992 and 1993.

These demonstrations, however, omitted the one aspect that is expected of the DICOM standard: interoperativity of heterogeneous systems. The DPNs represented development of various companies and various forms of implementation but were not diagnostic workstations as installed in many radiology departments. Digital diagnostic modalities such as CT, magnetic resonance imaging, computed radiography, ultrasound, and nuclear medicine systems produce valuable information in digital form that is incompatible and often undecipherable for general usage. Although the *info*RAD demonstrations did not address this problem of heterogeneity, they made a significant contribution to clarification. Twenty-eight companies that participated in these demonstrations were able to design and construct in a short time a DPN (or DN, as it was called for the 1993 demonstration) that proved capable of communicating with the CTNs according to the DICOM 3.0 standard. Therefore, although not proven successful, direct communication according to the standard is fully plausible. Supplying information to the DPN and DNs from image-generating equipment is a company-specific task. If a company demonstrated that it could produce DICOM-conformant communication with a DN, it should be equally capable of moving data from proprietary imaging equipment into such a DN.

The 1994 *info*RAD demonstration will encourage live communication between DICOM stations and diagnostic workstations of their product line.

The real-world implementation will, therefore, combine heterogeneous imaging equipment, DNs, or gateways into a homogeneous environment and other systems that are compatible, by design, with the homogeneous PAC system.

Reference

1. Horii SC. Hill DG, Blume HR, et al. An update on ACR-NEMA standard activity. J Digit Imaging 1990; 3:146–151.

The Mallinckrodt Institute of Radiology Prototype CTN Software

Steven M. Moore

The Mallinckrodt Institute of Radiology (MIR) software was developed in two stages. The software developed in 1992 supported the completed part 8 of the DICOM standard but used images and messages from ACR-NEMA Version 2. The 1993 software provided a DICOM implementation that was based on the DICOM V3.0 draft standard (September, 1993) that was balloted and approved by NEMA (October 1993). The 1993 CTN software supported image transmission (store, query, and move), printing on remote printers and communication in an HIS/RIS/PACS environment.

The software is written in ANSI C and tested on UNIX-based workstations as offered by Sun Microsystems, Digital Equipment Corporation, and Silicon Graphics. Some MIR CTN software that uses calls to the operating system may not compile under other versions of UNIX (for example, as supplied by Hewlett Packard) but can be easily modified.

The MIR software consists of the following pieces:

1. Subroutine libraries
2. Demonstration programs
3. Test programs
4. Documentation

Some subroutine libraries were designed and written to support various parts of the DICOM standard. These libraries served as the infrastructure for a number of the MIR demonstration and test applications. An example of such a library was the software written to implement the DICOM upper-layer protocol defined in part 8 of the standard. Other subroutine libraries were written to support particular needs of demonstration programs that are not direct requirements of the standard. An example of such a subroutine is the code which supports error messages.

Demonstration programs were written to fulfill specific requirements and to demonstrate particular aspects of the DICOM standard. The applications that were used in the

1993 RSNA DICOM demonstrations in the *info*RAD area are described below.

- An image server program was developed that supported DICOM communications for storage and retrieval of images. Vendors could send images to the image server using the DICOM storage SOP classes and could retrieve the same or other images using the DICOM query-and-retrieve SOP classes. The image server also supported the verification SOP class. To be specific, the image server supported the storage, query-and-retrieve, and verification SOP classes as an SCP.
- An image client program was developed that supported DICOM communications for sending images to vendor nodes. The image client program allowed users to login and list studies and images that had been stored by the image server. The image client program allowed the user to send images (complete studies) to a vendor node using one or more of the DICOM storage SOP classes. The image client program was an SCU of the verification and storage SOP classes. The image client program did not perform DICOM query-and-retrieve functions. A print manager program used a fixed set of images stored in simple database and allowed a user to establish a print session with a DICOM printer to print the images. The print manager had an Athena widget–based graphical user interface that presented print information to the user and allowed the user to set parameters for a DICOM print session. The user could also manipulate iconified versions of images to control placement on the print page (film). As the user manipulated the print parameters and icons, the print manager sent DICOM print commands to a vendor's printer. A full, basic print session was completed. The print manager implemented the Basic Grayscale Print Management Meta SOP Class as an SCU.

Two other applications were developed for the 1993 RSNA DICOM demonstration but were not actually used during the RSNA annual meeting. Two applications were written that simulated the interaction between an HIS and a PACS. The simulated HIS presented a graphical user interface that allowed the user to enter information into a simple HIS and to send event reports by means of DICOM communications to an external (vendor) node. The user could trigger numerous event notifications such as Study Scheduled, Study Completed, and Patient Created. The simulated HIS also included a server that had access to the same database. External (vendor) applications could establish DICOM associations with the HIS server and retrieve (DICOM N-Get) information from the server.

The simulated PACS performed a set of functions designed to complement the simulated HIS. The simulated PACS had a server program that accepted event reports from an HIS. The simulated PACS also had a graphical user interface that displayed event reports to the user. In response to event notifications, the user could direct the PACS to query the HIS to retrieve additional information. This retrieval was implemented with DICOM communication.

A number of test programs were developed with the MIR software. These programs allow developers to create, examine, and modify DICOM information objects, establish simple DICOM associations to test connectivity and DICOM functionality (store, query, and echo), and test the internal facilities (database and queues) that were developed to support demonstrations.

The MIR software contains documentation that describes the following:

1. Overview of the RSNA DICOM demonstration and the functions provided by the MIR software.
2. Examples of protocol data units that help the reader understand part 8 of the standard.
3. Installation and test procedure.
4. Guide to using demonstration and test applications.
5. Programming guides to all subroutine libraries.

As mentioned above, the MIR software contains a number of subroutine libraries that are used to implement the various parts of the DICOM standard. Included below is a short description of the subroutines that provide this support. Other subroutine libraries are included and documented with the software but are not listed here.

DCM – DICOM Information Objects
The DCM facility provides functions for manipulating DICOM information objects. These routines encode and decode objects per part 5 of the standard and allow the caller to perform simple operations (add, delete, modify) on individual elements.

DUL – DICOM Upper Layer Protocol
The DUL facility provides routines for implementing the DICOM upper-layer protocol with TCP/IP. The routines are used to create and tear down associations and to exchange data over established associations.

IE – Information Entity Verification
The IE facility provides functions for examining DICOM Information objects to make certain they conform to the rules specified in part 3 of the standard.

MSG – DICOM Messages
The MSG facility defines a set of fixed structures that contain the parameters for the request and response messages defined for the DIMSE-C and DIMSE-N services. The facility provides functions for translating these structures to and from the DCM representation of DCM information objects so the messages can be sent to and received from a peer application over an association.

SRV – DIMSE Services
The SRV facility supports the DIMSE-C and DIMSE-N services by controlling messages which are sent to and received from the network. This facility provides a general framework that allows applications to actually implement

the service classes defined in part 4 of the standard.

UID – Generate and Maintain Unique Identifiers
The UID facility provides a simple mechanism for generating unique identifiers in accordance with requirements of the DICOM standard.

As a side note, the functionality of demonstration programs depends on the evolution of the standard and requirements for demonstrations at the RSNA. Some MIR demonstration programs support odd features that are direct requirements of operating in a demonstration environment. As new requirements arise, demonstration programs may be replaced with a new version of the program or may be retired as the developers, RSNA, and NEMA find different ways to demonstrate the DICOM standard.

European CTN Implementation

Andrew Hewett, PhD
Peter Jensch, PhD

As part of the RSNA '93 *info*RAD demonstration of DICOM 3.0, a European central test node (CTN) was developed. Under the auspices of CEN (the European Standardization Committee), several institutions have cooperated to produce a European CTN implementation. Oldenburg University and the OFFIS Institute in Oldenburg, Germany, coordinated the development effort as well as implemented the CTN network software, DICOM information object encoding and decoding, CTN display and performed system integration activities. CERIUM in Rennes, France, developed the DICOM storage and query/retrieve service classes and associated database functionality. PRIMIS in Brussels, Belgium, has concentrated on producing sample sets of DICOM images.

For the purposes of work package separation and understandability, the breakup of software modules closely follows the various parts of the DICOM standard. In particular, a simple interface was defined between the software components developed in Oldenburg and those developed in Rennes. In order to efficiently cope with additions and changed in the DICOM data dictionary before it was final-

ized, a code generation facility was used to generate tag, value representation, and type definitions from tables extracted from electronic versions of the DICOM documents. Also considered were general mechanisms for handling sequences of items that will be particularly useful for implementation of DICOM media storage. The European CTN display was designed to be able to handle many vendors being assigned to a single CTN. Only the most recent activities are visible in the display, and image areas are not assigned to fixed vendors. The OFFIS Institute in Oldenburg has also developed software for exporting DICOM images into other formats. One external format considered was TIFF, which is useful for exporting to desktop publishing applications. Another format is image processing interchange (IPI), which is an ISO standard and is likely to be of particular importance in image processing applications.

All involved institutions are continuing development of DICOM software. In Oldenburg, work has already started on an object-oriented library for manipulating DICOM information objects. DICOM print client and server software is also under development.

The European DICOM software (source code and documentation) is publicly available and can be obtained via Internet FTP (ftp.uni-oldenburg.de in the directory /pub/dicom/dicom_software/European).

CHAPTER 4
A. Products and Vendor Strategies

Real-World Implementation Requirements

Robert Hindel, PhD

Figure 1 shows a "message generator" patterned after the parts of the DICOM standard. A key information structure is the "message" and its fragments, the PDUs. The standard does not make a clear distinction between the overall message and its fragments into PDUs, it equates a PDU with a message. The term "global message" could be used to refer to a block of data comprising a complete transfer. For technical reasons the global message is fragmented into PDUs. Such a PDU consists of an SOP and an association control header as indicated in Figure 1.

HOMOGENEOUS ENTITIES VERSUS HETEROGENEOUS ENVIRONMENTS

Implementation of the DICOM standard establishes an open system in the sense that communication between heterogeneous environments can be accomplished by means of homogeneous (standardized) information entities.

PDUs are standardized and transportable entities. They are generated by application entities (AEs) capable of performing certain tasks. It is important to remember that AEs are programs residing in "real-world" equipment, for instance a workstations (1). On the same workstation reside other programs possibly suitable for converting proprietary data from an image acquisition system into data conformant with the DICOM standard. The AEs are nodes on the chosen network as specified in the Conformance Statement.

ESSENTIAL FACILITIES

The essential facilities are called DIMSE and ACSE in the DICOM language: DICOM message service elements (DIMSEs) and association control service elements

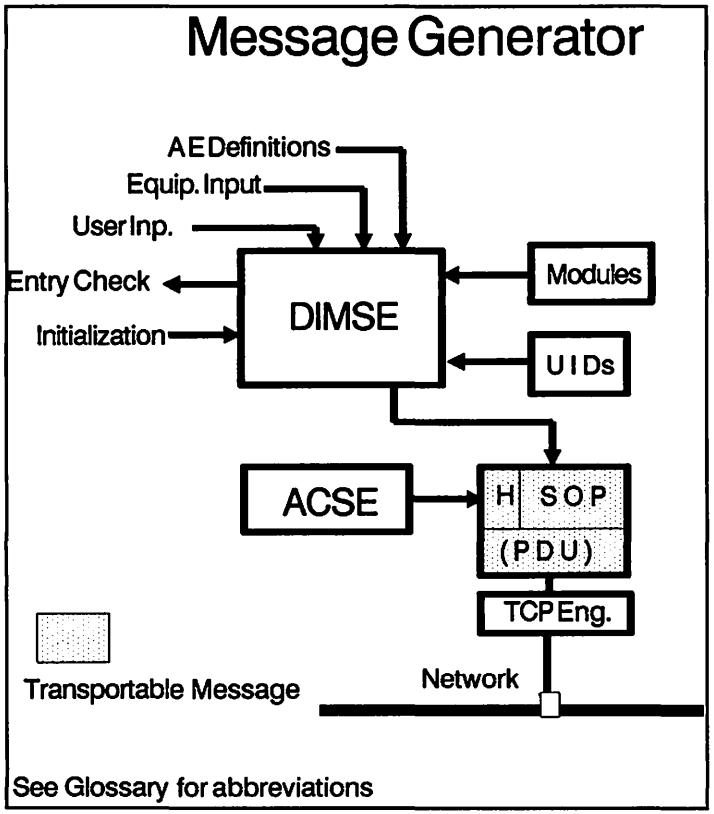

Figure 1.

(ACSEs). One can think of such DIMSEs as a message generator that uses various supplies of information. As indicated in Figure 1, IOD modules supply information data and command elements. A dictionary of UIDs supplies appropriate UIDs for the AE.

The calling AE must use the data format of the IOD modules and enter the appropriate data values coded according to the VR specifications. A list of specified modules is included in Table 1, and Table 2 gives a specific example for a set of CT modules.

A specific AE implemented on a particular computer platform and a specific network node will use a particular implementation program while another AE on another platform and node uses different software, but the same IOD module will be used to generate the same information ele-

ments. But both nodes (i.e., workstations on the network) can reverse roles and understand the PDUs generated by the other node. The essential prerequisite is conformance of the PDUs and their interpretations.

SOURCES OF DATA ELEMENT VALUES

The attributes of the required information objects are expressed by data elements. The values of the data elements are derived from several sources, e.g. :

- equipment and data links to image generating systems, preferable via automated transfer;
- a network connection to an RIS or HIS; and
- keyboards or bar code readers, which may require checking and verification.

The standard lists 545 data elements in 12 groups with new ones being suggested for various new information objects. Table 2 lists only data elements of types 1 and 2, but this may not be sufficient for a PACS installation. Some optional data elements will be needed and a response to all of them is required.

THE ASSOCIATION CONTROL SERVICE ELEMENTS

The ASCEs define a capability for establishing and terminating an association according to part 8 of the standard. All PDUs include a header dealing with such association primitives. The last 4 bytes of the ASCE header constitute the message control header, which indicates whether the following PDU contains data or a command and whether it is the last of such PDUs.

Figure 1 illustrates only PDU generation by a calling AE. A corresponding "engine" is required at the called AE. Incoming packets are reassembled by the TCP/IP engine into PDUs, which, in turn, must be checked for errors or

omissions such as missing mandatory information elements. In such a case, the existing association will be discontinued and a new association in the reverse direction will be established in order to report the omission.

If the called AE does not have sufficient storage space for a complete image, the calling AE must be informed.

Global Design Requirements

A real-world implementation will deal with various AEs performing a variety of tasks. The DICOM standard does not deal with such an aspect. Part 1 states:

> "The DICOM Standard does not specify:
>
> "The overall set of features and functions to be expected from a system implemented by integrating a group of devices each claiming DICOM conformance."

Checking the Conformance Statements of two systems may not be sufficient. All participating nodes must be compatible with respect to the intended tasks (SOPs and AEs). This may mean that a valid response to all of the optional data elements must be incorporated. The *info*RAD demonstrations addressed only a limited number of nodes and AEs and a limited number of data elements.

In a real-world implementation, the nodes (physical workstations) will play various roles and activate corresponding AEs. A global mapping is needed so that all required tasks can be performed without discrepancies or duplications. Such a global design will also generate a list of UIDs (2).

Part 3 of the standard lists the modules in Table 2.

Table 1

General	common (module)		
Patient			
	Relationship of UIDs		
	Identification		
	Demographic		
	Medical		
Visit			
	Relationship		
	Identification		
	Admission		
	Stay		
	Discharge		
	Schedule		
Study			
	Relationship		
	Identification		
	Classification		
	Scheduling		
	Acquisition		
	Read		
Results			
	Relationship		
	Identification		
	Impression		
	Interpretation	ID	
			State
			Recording
			Transcription
			Approval
Images			
	Patient Module		
	Study		General
			Patient
	Series		General
	Equipment		
	Image		General
			Pixel
	Modality		
			Computed Radiography
			Computed Tomography
			Digital Subtraction Angiography
			Magnetic Resonance
	Nuclear Medicine		
			Cardiology
			Ultrasound
			Secondary Capture
	Overlay Plane		
	Curve		
	Look-up Table		

Table 2
CT IOD Module

Module	Elements	Tag	Type
SOP	SOP Inst UID	0008,0018	1
	SOP Class	008,0016	1
Patient	Name	0010,0010	2
	ID	0010,0020	2
	Date of Birth	0010,0030	2
	Sex	0010,0040	2
Study	Date	0008,0020	2
	Time	0008,0030	2
	ID	0020,0010	2
Series	Modality	0008,0060	1
	Series No	0020,0011	2
Frame of Reference	UID	0020,0052	1
	Pos. Ref. Ind.	0020,1040	2
Equipment	Manufacturer	0008,0070	2
	Institution	0008,1040	3
Image General	Image No	0028,0030	2
	Pat. Orient.	0020,0020	2C
	Image Date	0008,0023	2c
	Image Time	0008,0033	2C
Image Plane	Spacg	0028,0030	1
	Image Orient.	0020,0037	1
	Image Posit.	0020,0032	1
	Slice Thickn	0018,0050	2
Image Pixel	Samples/Px	0028,0002	1
	Phot. Inter.	0028,0004	1
	# Rows	0028,0010	1
	# Columns	0028,0011	1
	Px. Asp. Rat.	0028,0034	1C
	Bits Alloc.	0028,0100	1
	Bits stored	0028,0101	1
	High Bit	0028,0102	1
	Px Repres.	0028,0103	1
Contrast	Bolus	0018,010	2C
Overlay	# Rows	60xx,0010	1C
	# Columns	60xx,0011	1C
	ROI	60xx,0040	1C
	Origin	60xx,0050	1C
	Bits alloc.	60xx,0100	1C
	Bit pos.	60xx,0102	1C
	Overlay Data	60xx,3000	1C

Forty mandatory data elements are required in 11 modules. Some of these data elements can be supplied through interfaces from a RIS or HIS. For instance, for scheduled studies the patient's name, identification number, date of birth, and sex can be transferred. The CT scanner could provide image number (0028,0030), image date and time, and manufacturer's identification number (0008,0070). The "Series No" (0020,0010) could be linked to the "frame-of-reference UID" (0020,0052) and the position reference indicator (0020,1040).

Most of the pixel information can be determined by the choice of CT examination, e.g. pixel spacing (0028,0030), slice thickness (0018,0050), etc. All of the data elements of the image pixel module are machine related and constant for a particular CT system. Overlay data elements are also fixed for a particular CT display system. Overlay information, though, is usually put on CT images in visual, not binary, coding.

The operator may have to enter the SOP class instance UID (0008,0018) and the frame-of-reference UID (0020,0052).

A user-friendly design would provide templates for studies with preset data elements and interfaces to other systems that supply required data elements. Type 2 data elements must be listed but can be entered later. An individual implementation may include optional data elements (type 3). Participating AEs of a global design must be capable of recognizing these and take appropriate action. Therefore, a CT template may contain more than 40 data elements.

All this requires nontrivial design of hardware and software. It is unrealistic, though, to expect error-free entry of all these data elements by an operator. Operator entries should be reduced to the absolute minimum and should be supervised by an entry checking and correcting algorithm.

DICOM 3.0 implementations are expected to provide robust and efficient access to imaging information. Entry of the required data elements must not slow down the technologist. The standard does not deal with the complexity of this task, but the implementer must. Implementation and

interfacing products, described later in this chapter, will supply information related to this task.

References

1. Bennet W, McIntyre J. Understanding DICOM 3.0 Rochester, NY: Kodak Health Imaging Systems Inc., 1993.
2. Hindel R. The DICOM 3.0 standard and the real world. Proc SCAR '94. Carlsbad, Calif: Symposia Foundation, 1994; 517–522 .

Example of a C-Store Request

Supplied by Steven M. Moore

In this example, an SCU of the CT storage SOP class has a stripped CT image. The stripped image is used to reduce the size of the example. Several data PDUs are presented that show the C-store command and the data set (CT image) that complete the C-store message.

Byte	Value	Interpretation
1	04	PDU Type : P-DATA
2	00	Reserved
3	00 00 00 81	PDU length: 129
7	00 00 00 7D	PDV length: 125
11	01	Presentation Context ID
12	03	Message Control Header
13	00 00 00 00	TAG group length
17	04 00 00 00	Element length
21	76 00 00 00	Group length
25	00 00 02 00	Affected SOP Class UID
29	1A 00 00 00	Data length
33	31 2E 32 2E 38 34 30 2E 31 30 30 30 38 2E 35 2E 31 2E 34 2E 31 2E 31 2E 32 00	1.2.840.10008.5.1.4.1.1.2
59	00 00 00 01	Command Field
63	02 00 00 00	Length
67	01 00	1 = STORE
69	00 00 10 10	Message ID
73	02 00 00 00	Length
77	01 00	Message ID
79	00 00 00 07	TAG, Priority
83	02 00 00 00	Length
8	00 00	Priority 0
89	00 00 00 08	TAG Data type
93	02 00 00 00	Length

97	00 00	Type 0
99	00 00 00 10	TAG SOP affected instance
103	24 00 00 00	Length 36
107	31 2E 32 2E 38 34 30 2E 31 30 30 30 38 2E 35 2E 31 2E 34 2E 31 2E 31 2E 32 2E 36 00	1.2.840.10008.5.1.4.1.1.2.5

The second PDU contains one DATA PDV. The data set in the PDV contains the beginning of the CT image. The rest of the PDU has been discarded for the sake of brevity.

byte	Value	Interpretation
1	04	PDU type: P-DATA
2	00	Reserved
3	00 00 40 00	PDU length (16384)
7	00 00 3F FC	PDV length (16380)
11	01	Presentation context ID
12	00	Message Control Header
13	08 00 16 00	TAG SOP Class ID
17	1A 00 00 00	Data length
21	31 2E 32 2E 38 34 30 2E 31 30 30 30 38 2E 35 2E 31 2E 34 2E 31 2E 31 2E 32 00	1.2.840.10008.5.1.4.1.1.2
47	08 00 18 00	TAG SOP Instance UID
51	24 00 00 00	Data length (36)
55	31 2E 32 2E 38 34 30 2E 31 30 30 30 38 2E 35 2E 31 2E 34 2E 31 2E 31 2E 32 2E 35 00 00 00 00 00 00 00 00 00	1.2.840.10008.5.1.4.1.1.2.5
91	08 00 20 00	TAG :study date
95	08 00 00 00	Data length
99	31 39 39 33 30 35 31 38	19930518
107	08 00 60 00	TAG Modality
111	02 00 00 00	Data length
115	43 54	CT
117	10 00 10 00	TAG Patient's Name
121	14 00 00 00	Length
125	4A 45 46 46 45 52 53 4 4E 5E 54 48 4F 4D 41 53 5E 5E 5E 20	JEFFERSON ^ THOMAS ^ ^ ^
145	10 00 20 00	TAG Patient's ID
149	0A 00 00 00	Length

153	4D 34 39 39 37 30 39 36 36 20	M49970966
163	10 00 30 00	TAG Patient's Birthdate
167	08 00 00 00	Length
171	31 39 34 33 30 37 30 34	19430704
179	29 00 02 00	TAG samples per pixel
183	02 00 00 00	Length
187	01 00	1
189	28 00 04 00	TAG Photometr. Interpretation
193	0C 00 00 00	Length
197	4D 4F 4E 4F 43 48 52 4F 4D 45 32 20	MONOCHROME2
209	28 00 10 00	TAG # Rows
213	02 00 00 00	Length
217	00 02	(512)
219	28 00 11 00	TAG # Columns
223	02 00 00 00	Length
227	00 02	(512)
229	28 00 00 01	TAG: bits allocated
233	02 00 00 00	Length
237	10 00	(16)
239	28 00 01 01	TAG: bits stored
243	02 00 00 00	Length
247	0D 00	(13)
249	28 00 02 01	TAG: high bit
253	02 00 00 00	Length
257	0C 00	(12)
259	28 00 03 01	TAG: pixel representation
263	02 00 00 00	Length
267	01 00	(1)
269	E0 7F 10 00	TAG: Pixel data
273	00 00 08 00	(524288)
277	00 80 00 80	(pixel data....)

There are a number of P-DATA PDUs that contain pixel data. The final PDU also contains pixel data but is of interest because it is the last PDU in the C-STORE message.

Byte	Value	Interpretation
1	04	PDU type : P-DATA
2	00	Reserved
3	00 00 01 0E	PDU length: 270
7	00 00 01 0A	PDV length: 266
11	01	Presentation context ID
12	02	Message Control Header
13	.....	Remaining pixel data

CTN Software in Public Domain

Robert Hindel, PhD

The Electronic Radiology Laboratory of Mallinckrodt Institute of Radiology (MIR) has produced a comprehensive CT prototype software that is offered for public use. It is available via Internet and also in document form and on computer medium from RSNA.

The following announcement was made on February 8, 1994:

SOFTWARE RELEASE NOTICE

The Radiological Society of North America and The Mallinckrodt Institute of Radiology are making available in the Public Domain, the software developed for the RSNA 1993 DICOM demonstration. This release includes source code and all of the accompanying supporting documentation.

This software was developed to enable demonstration of an implementation model according to the specifications from the DICOM 3.0 standard. It allows digital medical image communication over "open system" networks between multivendor and multimodality imaging devices.

You may obtain the software and documentation, free of charge, from the following Internet sites supporting the file transfer protocol (FTP).

rsna.org [192.203.125.2]
wuerlim.wustl.edu [128.252.118.15]

If you do not have access to the Internet and you would like to obtain a tape containing the software and a hardcopy binder of the documentation you may choose to order it (for a fee) from:

Radiological Society of North America
Department of Informatics
2021 Spring Road, Suite 600 • Oak Brook, IL 61021
708-571-7810

Formats:

1. Anonymous FTP - Software Source Code and Postscript Documentation (free)

2. Anonymous FTP - Software Source Code
   Mail Order - Hardcopy Binder Documentation
   (fee of $175)
3. Mail Order - Software Source Code on
   8-mm Tape or 1/4" Cartridge Tape
   Hardcopy Binder Documentation
   (fee of $250)

Four sites are offering Internet downloading of the DICOM documentation and the CTN software :

MIR	wuerlim.wustl.edu	128.252.118.15
RSNA	rsna.org	192.203.125.2
PSU	ftp.xray.hmc.psu.edu	
	http://www.xray.hmc.psu.edu	
U. of Oldenburg	ftp.uni-oldenburg.de	

A review of the three U.S. logs resulted in the following estimates :

MIR:	149	TOTAL accesses
	85	identifiable
	32	US *.edu
	26	US *.com
	27	International
RSNA:	600	total accesses
	229	separate addresses
	91	by numbers

PSU: In the first 4 months of 1994
>2000 total accesses

Software related accesses only :

16	US *.edu
30	US *.com
35	International
10	European software

B. Commercial Implementation Strategies

Agfa's Implementation Strategy

Carsten Weise

Agfa's IMACS product line is based upon the products MG 3000, LR3300, DI2000, AS3000, RS3000/5000, TS5000, and PS5000. From the start, Agfa took the strategic decision to benefit from the DICOM 3.0 standard.

For each of the products mentioned above, Agfa defined the required implementation of DICOM service class, resulting in the inherent DICOM Conformance Statement.

The newest equipment — the thermosublimation printer DI2000 — is conforming to DICOM 3.0 print management service class.

Existing equipment such as the PS5000 of Agfa's phosphor plate system will be upgraded to DICOM conformance through a software upgrade.

Agfa's network is based on Ethernet IEEE 802.3, whereon TCP/IP with DICOM 3.0 is implemented.

The requirements for interfacing to Agfa equipment are thus restricted to matching the DICOM Conformance Statements of third-party equipment with Agfa's. Therefore, Agfa provides the DICOM Conformance Statements of the products to the third party. Hence, the third party has all relevant information for the developing the interface to Agfa equipment.

The following Table summarizes the relevant DICOM service classes to which the Agfa products conform with respect to third-party interfacing.

Detailed product information is available from :

Bob Cooke, Product Manager
Agfa Division of Miles Inc.
100 Challenger Rd.
Ridgefield Park, NJ 07660
Telephone: 201-440-2500

Applicable Service Classes

Product	Verif	Storage	Stdy/Not	Query/R	Prt Mg	Pat./St Res Mg.
MG3000 LR3000	U/P	U/P	U		P	
D12000	U/P	U/P	U		P	
AS3000	U/P	U/P	U/P	U/P	U	U
RS3000	U/P	U/P	U/P	U	U	U
TS5000	U	U	U		U	U
PS5000	U	U	U		U	

Note.—P = provider, PAt/St. = patient study, Prt Mg = print manager, Query/R = query/retrieve, Res. Mg. = results management, Stdy/Not. = study/notification, U = user, Verif. = verification.

Source.—Reprint courtesy of Agfa-Gevaert N. V.

CEMAX Inc.

Craig Cornelius

CEMAX, Inc. offers a variety of DICOM services in its product line.

ClinicalView acquires images from a wide variety of sources, distributes them to designated image review stations, and displays them on high-resolution displays in the clinical ward.

VIP is a full-function radiology image processing workstation, offering image display and analysis, two-dimensional (2D) and three-dimensional (3D) image reconstruction, and advanced protocols for productivity in radiology.

ACR-NEMA 1.0 and 2.0 formatted data is accepted from CT, MR, and digital subtraction angiographic image sources and stored in CEMAX's database format for display, archive, reformatting and other image processing, or export. Data from any source can be exported in ACR-NEMA 2.0 format, including original data and 2D and 3D reconstructed images. Complete 3D image geometry is included with each image.

In both ClinicalView and VIP, DICOM 3.0 storage service class provider is an integral part of CEMAX's ImageServer 1.0 product. It supports acquisition and stor-

age of computed radiography, CT, MR imaging, ultrasound, and digitized film modalities. Original images obtained from scanners as well as derived 2 D and 3D reconstructed images are accepted.

CEMAX ImageServer exports original and reconstructed images as a DICOM storage class user. Image sets for export can be accepted at the individual image, series, or patient levels. Exported 3D images are exported as 8-bit gray-scale, RGB, or RGBA image objects. DICOM 3.0 image geometry data is included with each image to enable cross-referencing between images.

CEMAX's Network Film Server employs the DICOM print management service class to film to all major laser cameras. Via its LaserLink interface, Network Film Server acts as print service class provider for DICOM basic grayscale print management service-object class.

Network Film Server also incorporates a print management service class user for printing to cameras that accept the DICOM print protocol.

CEMAX provides the DICOM 3.0 query/retrieve service class user capability for database access via patient identification number (ID), patient name, study, or series ID. Retrieval is allowed at the patient, study, series, or image level.

Additional information on CEMAX products and DICOM-conformant services can be obtained from Matthew Long, telephone 510-770-8612; fax 510-770-8555.

Keeping Your Options Open: GE's DICOM-based Strategy for Building Tomorrow's Information Network

Don VanSyckle, Tery Sipple-Schmidt

No one can say with any great degree of certainty exactly what the global healthcare delivery system will look like in 5 years, or 20. But before your hospital invests in an image information management system designed to take it well into the 21st century, with an eventual cost likely to range upwards — perhaps well upwards — of $3–$5 million, you would do well to give careful thought to the impact that decision will have on your entire hospital. False starts can carry an outrageous price tag in this critical area, effectively locking you into technology that may prove totally inadequate to meet tomorrow's needs.

WHAT DO WE KNOW FOR SURE ABOUT FUTURE NEEDS?

Limiting your sights to the departmental level is yesterday's mindset. And the old PACS model, which focused primarily on eliminating film, falls far short of need. Simply duplicating "the way we've always done things" electronically ignores the clinician's needs and does little to improve the process — and your productivity. Yet unfortunately, most of the "solutions" on the table today are based on that outdated model ... rather than taking a longer view that can ultimately change and streamline the whole process by which health care is delivered.

Choices you make today can have a major impact on the flexibility of your system to accommodate these kinds of changes. It's analogous to buying last year's computer system to do what's available today versus one that has enough built-in capabilities to handle advances in technology for a long time to come.

THE MOST CRITICAL DECISION: DICOM OR PROPRIETARY?

Many decisions can best be made at the appropriate point in the development of the system. There is, however, one early decision which *must* be on target from the outset; the penalty for misguessing is too steep, in terms of quickly obsoleted equipment.

Primary among these, in our opinion, is the design of the

system based on proprietary versus industry-wide medical networking standards. The value of the proprietary choice to users is short-term only. But it's easy to see why it has a strong attraction for vendors. After all, if it's only with *this* vendor's brand of equipment that your network functions smoothly, are you likely to want to buy from another vendor in the future?

GE has chosen to take the longer view. Consider with whom you may need to exchange data asuse of remote diagnosis expands. What is the likelihood that each data transfer will be with an institution whose selection of systems mirrors yours? Can you really afford to be limited in that way? or to invest in costly, complex "gateways" that may or may not work consistently or interface with other networks?

To us, the only solution that makes long-term sense for the health care industry is a worldwide system of linkable networks, providing maximum flexibility through an "open" architecture based on industry-wide standards — in other words, a complete DICOM system.

DECISION TWO: WHAT VISION DO YOU LOOK FOR FROM A VENDOR?

Network systems vendors typically fit into one of six categories, listed here in order of increasing sophistication. Which approach you choose should depend on your own vision of the role of information management in your hospital for decades to come.

- **Digital Film Approach:** These vendors, usually film companies, recognize the probable movement toward a filmless radiology department and are reacting accordingly. They offer a simple electronic alternative to film, with no focus on broader connectivity or to change in the radiology productivity model.
- **Niche Market Approach:** Workstation suppliers are the most common entrants in this category. They focus on implementing the "optimum" workstation for one specific purpose — for instance, 3D images. There is limited inte-

gration of this station with the entire radiology diagnostic process with the rest of the hospital's data.

• **Generic Network Approach:** There are a number of vendors who understand physical networks very well but have little understanding about the unique information requirements, image analysis methods, and data flow needs associated with clinical applications.

• **Spigot Approach:** These vendors provide scanners or workstations that use the DICOM standard to send or receive radiologic images. It's up to you to locate vendors who supply complementary products such as local or wide-area network components and then to configure and integrate that network. If there are problems you will need to persuade each vendor to take responsibility for the malfunction.

• **Proprietary Solutions:** As described in the previous section, these vendors may indeed provide a solution that's integrated, department-wide. It may include anything from proprietary data formats to proprietary network protocols or storage devices. And it may work very well — as long as all devices on the network have the right brand name. These vendors may even claim DICOM compatibility, since they can sell you "gateways" (usually used only to get data into the proprietary network.) The problem is that these greatly reduce the functionality of the DICOM devices. They can also be expensive, and clearly inject an additional level of complexity, which may cause additional problems.

• **Integrated Solution:** A truly integrated system verifies that all devices on the network support the autoforwarding of all data needed to fill in workstation menu information, etc. This means that any vendor who understands radiology information and who supports an open architecture based on DICOM can provide the correct network and system components; you're not locked into any single source. And you can communicate freely with any other DICOM-based system, regardless of the manufacturer, without the need for gateways. Vendors capable of providing components, design and system integration will be able

to supply single-source accountability for network installation, scanner connectivity, workstations, HIS/RIS connectivity, and complete field service. This is the route that GE has chosen.

DECISION THREE: THE "BIG BANG" VERSUS THE PHASED APPROACH

Some of the dozens of vendors in this emerging marketplace have a broader vision of the ultimate goal than that provided by the old PACS model. But vision is only the first step. The difference is in the details; an implementation of the concept demands hundreds of design decisions, large and small. The impact of many of these will not be entirely clear until we as an industry have a good deal more experience in a variety of clinical sites.

There are essentially two approaches to this challenge:

- **The "Big Bang,"** or rush-to-judgment, technique says in effect, "Let's produce a total system to see how it all works together ... then go in later as necessary, to find fixes for the parts of it that cause problems for our users."
- **The Phased Approach** — GE's choice — lets you take the process one step at a time. By fine-tuning strategies as clinical practitioners discover how this automated process affects the work environment, we can better tailor your system to real-world conditions. This enables you to build upon previous phases without replacing earlier investments and gives real significance to your input in the configuration of your network.

We've identified four key phases as stepping stones to full realization of the vision:

Phase One: Establish the Infrastructure. This phase lays down the hardware necessary to build the "information highway," moving information from where it is acquired to wherever it is needed — based on the DICOM standard, to allow maximum flexibility in connecting most manufacturers' products in the future. Phase one systems support transmission of image data to any DICOM-supporting devices on the network. (See next section for current list.)

Phase Two: Automate the movement of image data from acquisition to display or storage. A network manager or server manages data flow, determines where it should be sent, and includes the ability to store images locally, wherever they are used. So that the system can be cost-effectively upgraded when and where needed, we've grouped systems in clusters; typically, each radiology department on the network would constitute one cluster. Each cluster can then advance to the next development phase independently, without affecting the overall performance of the system.

Phase Three: Link the radiology network into the hospital's information systems to retrieve patient demographics data and transfer scan information to other systems outside of radiology. Key to this phase is tying different archive systems together with a large, centralized archive system that is electronically accessible throughout the hospital.

Phase Four and Beyond: Combine diagnostic and other information from radiology and all the other departments, laboratories, and patient wards. This will be a larger challenge than it appears at first glance, since neither standards nor infrastructure exist yet. But with a phased approach, the task will be manageable.

HOW GE'S ID/NET INTEGRATES DICOM FOR MAXIMUM FLEXIBILITY

GE recognized the need for industry-wide standards well before such standards even existed; and we've been instrumental in their development. Over the past 4 years, many GE representatives have been assigned to the DICOM committees, edited several parts of the standard, and chaired a working group. We continue to be one of the most active contributors to its growth.

That means we thoroughly understand the DICOM standard. That understanding has already enabled us to integrate DICOM into a number of our own products, from the inside out , thereby demonstrating the effectiveness of its connectivity. Since January 1994, only a month after the

DICOM demonstration at the annual RSNA scientific assembly in 1993, we've introduced three DICOM-integrated image acquisition systems and two display, analysis, and storage workstations:

- CT HiSpeed Advantage
- CT HiLight Advantage
- MR Advantage Signa
- Advantage Windows Workstation
- Advantage Independent Console

And that's just the beginning. Coming up soon:

- X-ray
- R&F
- Vascular
- CT 9800
- CT ProSpeed
- CT Sytec
- MR Vectra
- Radiation Oncology Target 2
- PET Advance
- Ultrasound Logic 700
- And a complete line of DICOM-based teleradiology products

To maximize flexibility and lay the groundwork for an open architecture system, all these products will have DICOM integrated into each system. This assures that there will be no need for special translaters or "gateways" for communication with any other truly DICOM-based device or network.

We'll provide a wide range of DICOM-compatible systems, including acquisition, analysis, distribution, display, storage, and image management. We'll also provide system integration: consultation, design, installation, service, and support for both local and wide area networks (WANs). GE Global Networks group is experienced in the design of simple or complex WANs. And GE Service, using InSite OnLine, has more than 5 years of remote service expertise for network problem analysis. With single-source accountability for all communication needs, you can forget about dealing with such issues as LATA boundaries or T1 lines ... or about finger-pointing among various vendors.

And of course, with 99 years as a leader in the diagnostic imaging business, we thoroughly understand your medical imaging and information requirements. You can rely upon our commitment to helping you meet your growing connectivity needs, far into the future — with systems that exemplify the GE Continuum in action. ID/Net has been designed from the outset to keep going and going — keeping pace at every step with advancing technology.

The Connectivity Program of Philips Medical Systems

Kees Smedema

THE PAST

Connectivity, through electronic communication and through media, plays an important role in the product policy of Philips Medical Systems (Philips). One of the first entries in the PACS market, the CommView system, was jointly developed by Philips and AT&T. Commview is currently installed in many hospitals in the United States and Europe, and its development and use has provided a wealth of experience that is used in the new DICOM-based Philips Connectivity Program.

Prior to the ACR-NEMA standardization activities, Philips and Siemens cooperated in the development of the SPI interface definition. Especially for storage of images on disks, this has been used for a long time and is still supported on several Philips modalities and EasyVision workstations.

Philips' prevailing protocol for communication of images is PMSnet, which uses the second version of the ACR-NEMA standard. It is either directly available from the modalities through EasyVision workstations or through special interfaces offered in cooperation with Merge Technologies Inc. It is also used internally between Philips modalities and EasyVision workstations. In this case, extra application functionality can be provided through private attributes that are not yet standardized.

DICOM

Philips Medical Systems has actively supported the development of DICOM, which is the cornerstone of the new

Philips Connectivity Program. DICOM not only enables image communication between vendors but also increases the opportunity for PACS functionality. Therefore, the Philips DICOM program is closely linked with the Philips Connectivity Program to offer PACS functionality at various levels of sophistication from department levels to complete hospitals and beyond.

PHILIPS CONNECTIVITY PROGRAM

The Philips Connectivity Program is based on the following key points:

- Modalities will provide direct DICOM store services for the relevant imaging objects; for some older systems this can be realized through special gateways.
- The EasyVision product line consists of three product families:
  - —modality-oriented productivity enhancers
  - —stations for special clincial applications and
  - —general application-and-review stations
- DICOM store and query/retrieve service classes will be implemented for the objects that are relevant for the specific EasyVision workstation.
- Stations for distributed viewing (teleradiolgy and critical care) will use the DICOM store and query/retrieve service classes.
- For both modalities and EasyVision workstations the patient management service class will be supported and provide a standard interface to RIS systems. An RIS-DICOM server will be available in order to interface with RIS systems that are not DICOM compatible.
- DICOM media storage will be provided as soon as relevant standards are available (i.e., the completion of the parts 10, 11 and 12). Philips is actively involved in the standardization of an exchange medium for cardiovascular image series in order to replace film in this application.

- Relevant DICOM functionality for communicating images in radiation therapy and treatment planning will become available soon. Philips is trying to find support to extend DICOM to patient-related treatment information.
- The Philips PACS strategy is based on partnership with other vendors of the network services and the mutual validation of the DICOM services. This applies especially to archive vendors. Philips intends to have cooperation agreements with a few archive vendors in order to offer validated DICOM-based services between our modalities, workstations, and archives.

CONCLUSION

Philips Medical Systems is committed to provide DICOM interfaces in all relevant areas for images as well as patient management. Philips will continue to support the improvement, enhancement, and maintenance of the standard and will be participating in various DICOM working groups for further extension of DICOM functionality and to improve image quality in print management and to enable lossy compression.

Philips Medical Systems
P.O. Box 10,000 • 5680 DA Best, The Netherlands

Picker International's DICOM 3.0 Commitment

David Talton,
Jay Gaeta, PhD

Picker is committed to meeting the increasing demands of the health-care industry by offering networking and connectivity services which meet user requirements in a cost-effective fashion. DICOM plays a central role in such connectivity. Connectivity provides many benefits, including distribution of images within a single facility and to other facilities, off-line analysis, operational and data integration of imaging facilities with hospital information systems, and efficient use of capital equipment such as archiving systems and hard-copy devices. Picker is committed to providing open connectivity via DICOM, enabling extensive networks comprised

of Picker and third-party equipment. Picker assists customers in the design, installation, and servicing of such networks.

Picker has provided leadership in the development of DICOM standards, including DICOM 3.0, by its active participation in ACR-NEMA and various DICOM committees for many years. Picker participated in the *info*RAD demonstrations during RSNA '92 and '93 and is participating in this year's RSNA demonstration of DICOM. All Picker acquisition systems and workstations offer DICOM 3.0 capabilities, presently available and installed in the field. These products include our line of CT scanners (IQ, IQ-Premier, PQS, PQ-CT, and PQ-2000 systems), MR imagers (Merit, Vista, HPQ, Edge, and Asset), nuclear medicine systems (Odyssey & Prism), and x-ray devices (DSS and VMAX). All acquisition systems provide manual and/or automated export capabilities. All workstations provide query-and-retrieve, receive, and export capabilities. Active development continues in each of these product lines to provide additional functionality.

For more specific information on product functions, please contact the sales specialist or marketing department associated with that product, or call 1-800-323-0550.

Picker has placed Conformance Statements for these products in the public domain, and these statements are available in hardcopy format through our marketing department or over the Internet. Internet access to our conformance statements can be gained by sending e-mail to Jay Gaeta (gaeta@picker.com).

Picker DICOM 3.0 compliant products are already installed in many institutions including:

Penn State/Hershey Medical Center, Hershey, Pennsylvania
Veterans Administration Baltimore, Baltimore, Maryland
Mallinckrodt Institute of Radiology, St Louis, Missouri
Hospital of the University of Pennsylvania, Philadelphia, PA
University of Geneva, Switzerland
MetroHealth Medical Center, Cleveland, Ohio

Picker has an active program for validation of its products and Conformance Statements. Picker supports validation testing for interfaces to third-party systems.

Migration Path for an Existing Industrial PACS: SIENET

Rainer Thieme, Dipl Phys

Christian F. C. Greinacher, PhD

1. INTRODUCTION

Based on its long experience in engineering diagnostic imaging equipment, Siemens made a commitment to design and evaluate PACS systems from the very beginning and is now offering a PACS product family, called SIENET, individually configurable in a modular structured systems architecture (Fig1) (1).

Today, in addition, we know that medical professionals as well as hospital administrators can only gain advantages from the application-oriented improvements in PACS when the introduction of a PACS provides economical benefits for the institution, too. Without attempting to answer the still difficult question as to how to measure and prove the economic impact of any PACS installation, the cost efficiency of a PACS depends very much on its capability to interoperate with currently installed and future imaging modalities from different manufacturers. Moreover, it has to allow the integration of image equipment (such as image workstations, storage systems, and networks) purchased by the user from different manufacturers and to migrate into forthcoming technological solutions. In other words, a PACS will provide better economies when it is open to compete with and incorporate the best products from multiple

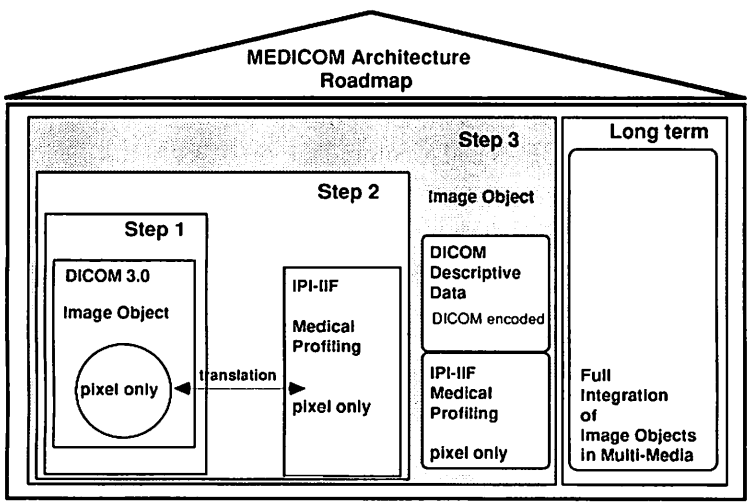

Figure 1. SIENET systems architecture.

vendors. The key word for this highest priority user requirement is standardization.

Therefore, it was an outstanding and successful activity when the American College of Radiology (ACR) and the National Electronics Manufacturers Association (NEMA) started in the early 1980s with the specification of the so-called ACR-NEMA digital imaging standard, which was published in 1985 as ACR-NEMA standards publication number 300-1985 (2).

As the scope of the ACR-NEMA standards publication number 300-1985 states, it was not the intention of the ACR-NEMA digital imaging working group at that time to specify an overall PACS or networking standard. In order to overcome this gap, Philips and Siemens started as a joint effort to work on the Standard Product Interconnect Specification (SPI), which was published in December 1987 (3). Siemens made SPI an internal standard for its digital diagnostic imaging modalities and implemented SPI into Siemens' diagnostic imaging and PACS products, step by step. With the knowledge gained from its practical PACS installations (4) and the SPI development effort (3), Siemens can provide its customers with the advantage of a wide spectrum of standardized diagnostic imaging equipment today. These products do meet the image and header formats as defined by the ACR-NEMA digital imaging standards publication and are fully compatible with all SIENET products (i.e., with all Siemens PACS components). The principles of SPI have been well accepted, and some of them have been adopted by the various working groups of the ACR-NEMA committee or ACC/ACR-NEMA committee, respectively; they are being worked on in the next generation of standards for digital imaging and communications in medicine (DICOM). Work in progress on the developing DICOM standard was presented by several companies during the RSNA annual meetings in 1992 and 1993. The new DICOM standard, at that stage, connected modalities to networks and defined functions for accessing and using these networks.

Siemens has supported this process but could not avoid

that the ultimate result was compatible with neither the former ACR-NEMA digital imaging standard version 2 nor with SPI. Nevertheless, Siemens prepared a migration strategy to make its products DICOM-compatible. Initial results were successfully demonstrated during the DICOM trial at RSNA '93.

2. MIGRATION TO DICOM

Siemens supported the idea of harmonization into an ACC/ACR-NEMA standard from the very beginning and, therefore, planned to migrate to DICOM, laying out two main requirements for such a migration already at a very early stage: first, to support the widely installed product palette with ACR-NEMA/SPI/PACSnet connectivity, and second, to provide a strong architectural platform for new product developments.

To meet these two requirements economically, a gateway between the world of DICOM and the established Siemens PACS environment together with a powerful DICOM toolkit to allow the successful development of new products were believed to constitute an efficient technical approach.

The Siemens DICOM Architecture

Due to Siemens far-reaching and extensive experience in digital imaging and networking within a medical infrastructure, the goal was to create a proven concept for integrating the installed base — without loss of information and performance — into the new concept of DICOM. Even in the initial product-definition phase, great importance has been attached to future compatibility and upgradeability in the ever-expanding and changing standardization process of image management and, in particular, of image management in medicine.

Software tools are the building blocks of the Siemens DICOM architecture:

- A **format library** to access and manipulate data structures of both DICOM and ACR-NEMA/SPI image objects;

- A **format converter** to convert between different image formats being used in various installed or newly developed products;
- A **communication toolkit** to establish and maintain communication between different users;
- A **set of services** to communicate objects between applications.

A very important issue was the interchangeability of images between existing (ACR-NEMA/SPI/PACSnet-based) and new (DICOM-based) products. Since DICOM introduces many new or changed modality-dependent attributes, this task was quite challenging. In order to catalogue and sort the requirements, Siemens introduced image **conformance levels**, not to be confused with the DICOM-defined Conformance Statement.

Siemens will classify DICOM images according to the following conformance evels:

Level 1: suitable for display (pixel and region of interest can be displayed)
Level 2: suitable for simple evaluation (histograms, etc.)
Level 3: suitable for reporting (image text [annotation] as patient, study, and measurement data can be displayed in the same way as displayed with the originating modality)
Level 4: suitable for hardcopy output, including text
Level 5: suitable for complex evaluation (3D, MPR, etc.)

The introduction of conformance levels substantially improves readability of a Conformance Statement. This is very important. As the DICOM standard states: "This Standard facilitates interoperability of systems claiming conformance in a multivendor environment, but does not, by itself, guarantee interoperability."

The extent to which interoperability can be expected between two or more systems is given in the Conformance Statement. The quotation from another section of part 2 of the DICOM standard — "By comparing the Conformance

Statement from different implementations, a knowledgeable user should be able to determine whether and to what extent communications might be supported between the two implementations." — clearly shows the importance of a Conformance Statement and the need for high readability.

The DICOM Gateway

Given the final publication of the DICOM standard by ACR-NEMA, the DICOM gateway will represent an immediate connection between the installed PACSnet /SIENET and DICOM products, based either on a TCP/IP or DECnet protocol stack. There are two solutions for a DICOM gateway:

- The classical solution sees the DICOM gateway as an additional piece of hardware (dedicated gateway workstation) with a SIENET/PACSnet and a DICOM interface;
- The integrated solution incorporates the gateway software as part of a PACSnet modality architecture (integrated software solution).

Figure 2 shows both possibilities. Depending on the requirements, the user will most likely choose one of the two solutions. The gateway will either run on top of a TCP/IP

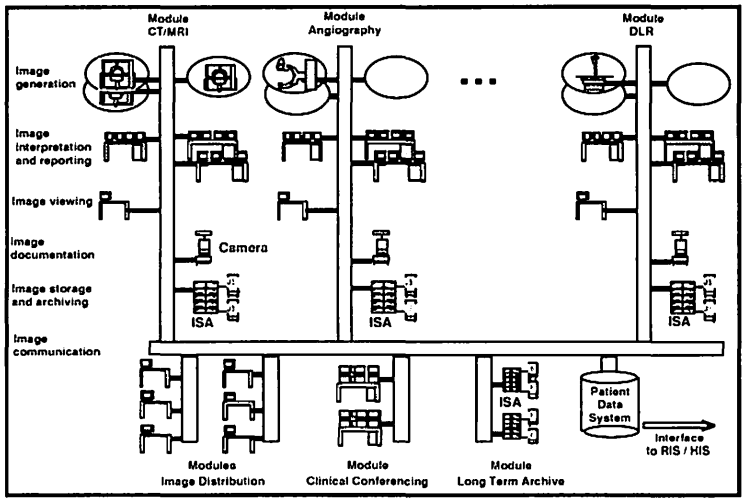

Figure 2. Modality interfacing options.

or a DECnet protocol stack.

With the DICOM gateway, Siemens created the basic component to migrate its modalities and SIENET products from the ACR-NEMA/SPI standard to DICOM. This means that the existing Siemens Protocol PACSnet is compatible with our DICOM implementation in both directions. It also means that all equipment from other vendors complying to the de facto standard SPI or to DICOM can be connected to either a PACSnet environment or to a DICOM product. In other words, wherever and whenever needed, Siemens can supply a DICOM-compatible Siemens modality or a DICOM-compatible comprehensive SIENET network. In addition, selected modalities and SIENET components (as indicated above) can directly implement the DICOM gateway and will, therefore, represent an integrated DICOM interface.

The DICOM Toolkit

The major objectives for the design of the DICOM Toolkit were software quality and program safety. The DICOM Toolkit consists of a set of software tools to facilitate the development of DICOM products. One highlight of the Toolkit is that its format library accesses ACR-NEMA and DICOM images with the same integrated data dictionary. Another aspect of the format library will be an on-line syntax checker for image validation. A semantics checker will be able to automatically provide a classification to a specific conformance level. Both "preprocessors" will enhance quality and liability of the interface between two applications. The format converter will provide a high quality of converted images from different format dialects by means of several ACR-NEMA, ACR-NEMA/SPI, and DICOM derivatives. The format converter will directly build upon the format library.

Since DICOM images are more "complete" (i.e., in simple words, the DICOM data structure contains more attributes), mapping from ACR-NEMA/SPI to DICOM can only be implemented with the support of the modalities that produce the images. Therefore, the conformance level of

Siemens images will generally be higher than that available from other vendors' sources.

Other important parts of the DICOM Toolkit are the software tools for establishing communication and a common API for using the services (e.g., send, receive, and query-and-retrieve tools). In further developmental phases, the DICOM Toolkit will also provide services for HIS-RIS interfaces between modalities, PACS systems and, ultimately, between health care information systems in general.

3. OUTLOOK

All the above-mentioned steps will lead to integrated DICOM systems from Siemens and other vendors of medical products. In parallel, Siemens will focus on a strategy for the future.

Customer Requirements

Digital imaging in general — not just medical imaging — and networking is still a very fast-growing technical field. In the near future, we expect a strong impact from multimedia needs. In this context, we are no longer in a pure medical environment, but have to deal with "medical objects" within a multimedia infrastructure. Today, we transmit medical images with possible annotations consisting of text (patient name, reports, etc.) and graphics (ROIs, arrows, and so forth).

Within a multimedia infrastructure, a medical image itself can be seen as an "annotation" of a multimedia hyperobject. Therefore, the demand for basing medical products on information technology (IT) platforms, plus added "medical attachments," will increase.

ISO / IEC — Imaging

ISO standard IPI (5), developed by a joint committee of ISO and IEC (ISO/IEC JTC 1 SC 24), can be used to define such a hyperstructure for a multimedia medical infrastructure mentioned above.

Siemens anticipated this evolution in health care. Therefore, Siemens participates in the development of IPI with

members of IT sections of the company, and the Siemens Medical Group is actively involved in the standardization of IPI.

CEN TC 251 — Medical Informatics

In close cooperation between vendors, users, and other standardization organizations (such as ISO, IEC or ANSI and JIRA), CEN TC 251 (the European Standardization Body) will create an evolution process and a migration strategy to reach the goal for open communication in medicine within this multimedia infrastructure.

Migration Strategy toward IT

Figure 3 shows the basic strategy of CEN TC 251. To guarantee upward compatibility to satisfy both vendors and users, CEN begins by adopting DICOM as a starting point for migration. In order to distinguish the activity of CEN from previous work by ACC, ACR, NEMA, and others, and also to show its origin, the "new" standard will be called MEDICOM (MEDical Image COMmunication), but MEDICOM could also be interpreted as "Multimedia Extended DICOM."

The first important step will be to establish a "registration authority" supported by the European Union and Industry to implement necessary updates to the standard in a safe, coordinated and documented way.

Slowly, MEDICOM will migrate toward an IT platform with the full support of Siemens. Step 2 will allow a translation of a DICOM-encoded image into an IIF-encoded (IIF [Image Interchange Facility] is part 3 of IPI) image, thus allowing any application direct access to an IT-IPI-PIKS implementation. (PIKS [programmer's imaging kernel system] is part 2 of IPI.) Step 3 will integrate this process into the MEDICOM object itself. Finally, step 4 will represent the above-mentioned hyperobject. All steps are based on the assumption that IPI will be broadly accepted by the information technology industry.

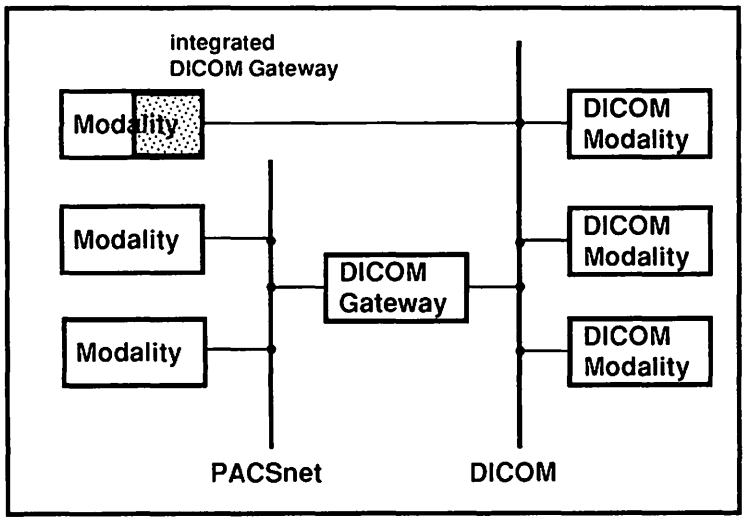

Figure 3. MEDICOM as a CEN strategy.

4. The Concept — There Is a Tomorrow

Siemens set up the following simple rules to reduce costs for developing software and increase benefits for the user (which also means reducing costs in providing health care):

- use existing software;
- reuse software already written;
- thorough software quality and software design to system safety.

Examples of existing software include operating systems, prototyping tools for designing user interfaces, tools for network access (e.g., ftp, CORBA [6], or, most important, software based on "standards" from the Information technology world like MIT's X11 or IPI, particularly implementations of PIKS for image processing or ASN.1 [7] parsers and generators for IPI-IIF data structures). Reusing software is an in-house process of structuring software development. A common software architecture builds the platform for modalities and PACS development to reuse software written in a "central" software team. Through stepwise introduction of object-oriented methodology and by building and maintaining object-oriented class libraries,

the probability of reusing "software packages" will drastically increase.

As in the past, Siemens will also prove in future that a sound system design together with emphasis on software safety will lead to high-quality products. Quality is the bottom line.

References

1. Greinacher CFC, Fuchs D, Perry J. Product-related advantages of a structured PACS architecture. Proc Comput Applications Med Care, October 25–26, 1986; 296–305.
2. Digital imaging and communications. ACR-NEMA standards publication no 300-1985. Reston, Va: American College of Radiology, 1985.
3. SPI Standard Product Interconnect for Compatibility of Digital Imaging, documents 1–6, version no 1, December 1, 1987.
4. Greinacher CFC, Semann B. SIENETr installations in routine use: technical commonalities, individual application scenarios, economical facts. Proc SPIE 1994; 2165: Medical imaging—PACS design and evaluation.
5. Image processing and interchange. International Standards Organization IS 12087, 1994.
6. Common object request broker architecture. Digital Equipment Corporation, Hewlett-Packard Company, Hyper Desk Corporation, NCR Corporation, Object Design, Inc., SunSoft, Inc. Revision 1.1, draft 10, December 1991.
7. Abstract syntax notation one. International Standards Organization IS 8824, 1987.

Interfacing and Software Products

Wayne T. DeJarnette, PhD

DeJarnette Research Systems Inc. (DRS) offers several products applicable for the implementation of DICOM 3.0 . The company has offered ACR-NEMA interfacing to imaging systems and other PACS components of various vendors. More recently, DRS has supplied interfacing equipment and services to the Medical Diagnostic Imaging Support project of the U.S. Army and has installed a major PACS system at the Baltimore Veterans Administration Medical Center.

SOFTWARE PRODUCTS

Introduction

DeJarnette Research Systems provides DICOM support to application developers with a series of software products. One of these products is the AN/API developer's toolkit. The AN/API provides the communication protocol, removable media support and message encoding required of a DICOM-conformant application. DICOM associations are requested and accepted as defined in DICOM parts 8 and 9. Removable media support adheres the rules specified in DICOM part 10. Messages are encoded in accordance with DICOM parts 5–7. The AN/API can therefore support all of the DICOM service-object pair (SOP) classes defined by DICOM parts 3 and 4.

Supported Platforms

The AN/API is available for many platforms and operating systems. AN/API libraries operate on any 16-, 32-, or 64-bit big or little endian processor. The AN/API automatically handles the byte ordering of the attributes when it sends or receives the DICOM message.

Most of today's major operating systems are supported by the AN/API. The list, however, is never complete. The AN/API continues to be ported to new operating systems as those systems become available for widespread use. The following operating systems are available today.

PC Operating Systems
- Microsoft DOS
- Microsoft Windows
- Windows NT
- OS/2

Unix Operating Systems
- SunOS
- Solaris
- OSF
- Silicon Graphics IRIX
- Hewlett-Packard HPUX

Macintosh
- System 7

Embedded Operating Systems
- VRTX
- pSOS

The AN/API can use any file system when reading or writing DICOM messages from or to disk. The file system may be local or remote, permanent or removable. On systems that have limited memory resources, the AN/API enables the application to use the disk as an alternate memory source.

Memory requirements for the AN/API library routines are minimal. The AN/API has optional library modules that may or may not be required by the application. If the module is not necessary, the corresponding library does not need to be linked into the application. The library's memory requirements varies according to the platform and operating system but typically requires 30 Kbyte of memory.

Operating systems that support dynamic libraries (DLLs, threads, etc.) can share memory resources by using the AN/API's dynamic linked libraries.

The AN/API supports the DICOM upper layer protocol (part 8) over TCP/IP and Decnet. The AN/API makes use of the system's native services. It supports Berkeley socket, Microsoft WinSock, and MacTCP programmer's interfaces for TCP/IP. DEC's network interface, Berkeley sockets, and Sun Microsystem's DNI interfaces are the

supported Decnet programmer's interfaces. Any media supported by the communication services of the operating system can be used by the AN/API. This includes Ethernet, FDDI, T1/T3, ATM, and standard phone lines.

The AN/API also supports the DICOM point-to-point communication protocol (part 9) with DeJarnette Research System's ANSIF driver and AT/ANSIF-HP interface board.

Installation

The AN/API consists of a set of linkable libraries and two data files. One of the data files contains all of the DICOM UIDs used for establishing associations with remote application entities. The other data file contains the supported data dictionary. Each of these files may be updated by the user as the DICOM standard evolves to include new SOP classes and attributes.

Installing the AN/API involves copying the libraries and data files to the development system. The AN/API is available on floppy disk and cartridge tape. Once installed, the AN/API is ready to use.

Included on the AN/API distribution media are a test application and sample client and server source code. The test application can be used to validate any of the AN/API functions. The sample source code shows how the AN/API can be used to build and parse DICOM messages as well as how to establish DICOM associations and transmit and receive those messages. The source code may be compiled and executed by the developer in order to test the library functions.

Software Functionality

The AN/API is an application developer's library. The application determines the peer with which it needs to communicate and calls AN/API functions to establish connections. Similarly, when a message needs to be generated, the application determines the information that is to be included in the message and calls AN/API functions that encode the information. When parsing a message, the applica-

tion requests the desired information and the AN/API retrieves it from the message.

Initialization and Configuration.—When the AN/API initializes, it defaults to a DICOM conformant configuration. The application developer has the ability to modify the configuration on various levels to better service the application. A modified configuration can be applied to the entire application, a single association, or a single DICOM data set. The AN/API's configuration can be modified to provide support for older versions of the ACR-NEMA standards and for other ACR-NEMA-like standards.

In addition to standard-related configuration parameters, the AN/API supports the modification of some runtime parameters. The application can configure the AN/API to suit the platform on which it will run, thereby optimizing its use of system resources and features.

DICOM Associations.—A DICOM association exists on top of an open protocol connection. The AN/API, after establishing the protocol connection, negotiates the DICOM association. The information used during the negotiation procedure is specified by the application.

When waiting for DICOM association requests from remote application entities, an application specifies the application context, including supported presentation contexts and user information, that it will accept. The AN/API, after detecting a request for an association,negotiates the association parameters by validating the requested context against the specified application context. If there is a match between the contexts, the association is accepted. Failure to match the requested context with the application-specified context causes the AN/API to refuse the association. When an association has been successfully negotiated, the AN/API returns to the application a handle to the association. The application is, at that point, able to send and receive DICOM data sets over the association.

Similarly, an application that wishes to request an association to a remote entity specifies the application context, including the requested presentation contexts and user information, to the AN/API. This information is used to build

and send an association request to the specified application entity. The result of the association negotiation is returned to the application. If the remote entity accepted the association, DICOM data sets may be sent and received over the new association.

DICOM associations may be released and aborted by the application entity. By making an AN/API function call, the association is terminated according to the rules of the DICOM standard.

DICOM Data Sets.—The most extensive part of the AN/API toolkit is its support for data-set encoding. The AN/API provides routines to build and parse DICOM data sets in addition to routines that can be used to provide the information necessary to identify DICOM attributes. The AN/API handles both implicit and explicit value representations (VRs). Coupled with its ability to support big and little endian encoding, the AN/API supports all of the defined transfer syntaxes.

The AN/API provides the application with the proper encoding for Command and Data data sets. Group length elements, when required or when configured to be inserted, are calculated by the AN/API.

The AN/API enables the application to perform the following data-set functions:

insert an attribute
retrieve an attribute
retrieve the next attribute
position the AN/API at a specific location in a message
rewind the message
link the message to a disk file
append a Command data set to a Data data set
resolve an attributes VR

Error Handling and Debug Capabilities.—The AN/API supplies a variety of error codes that identify anomalous situations. The AN/API handles errors by cleaning up any residual effects of the condition and returning the associated error. Certain error conditions, such as detected pro-

tocol violations, result in an automatic response as defined in the DICOM standard. The application does not need to handle such conditions itself.

Debug in the AN/API is extensive. The AN/API supplies run-time diagnostics that may be turned on and off at any time by the application. The AN/API can be configured to report error conditions and/or status messages. Error messages may contain the system error code, if available. Status messages contain information that indicates the current operation the AN/API is performing along with information about the operation. For example, AN/API status debug will print the contents of association request and response PDUs received when attempting to establish an association.

Diagnostic messages are directed to a routine that processes them. By default, this routine prints the messages to the standard error device. The application has the ability to specify its own diagnostic processing function. This capability enables diagnostic messages to be logged in a manner suitable to the platform on which the application is running. For example, the diagnostic messages can be directed to a status window on a windowing system.

Product Support

The AN/API is supported by DeJarnette Research Systems' customer support department. Questions concerning installation, usage, and behavior of the AN/API are accepted. Support is provided over the phone by dialing (410) 583-0680 and electronically by sending e-mail to support@dejarnette.com.

SYSTEMS

Imageshare 910

These are gateway systems capable of converting full 12-bit digital outputs of various imaging systems into standard format (DICOM 3.0. and earlier versions ACR/NEMA 2.0) The outputs are compatible with LANs and WANs. Specifically, the following systems can be interfaced :

GE	CT 9800 Quick	MR Signa Advantage 5.x
	CT 9800 HTD	MR Signa Advantage 4.x
	9800 Hilight Advantage	Advantage DX
	Hilight Advantage	GE Adv. Independent Console
	HiSpeed Advantage	CT 9800 Independent Console
	Pace Model (1994)	Advantage Windows Workstations
Siemens		
	Somatom	Litebox
	Magnetom	DVC, DRC Workstations
	Impact MR	ISA Archive
		ECAT
Philips		
	CT LX, TX, CX	
Picker		
	PQ2000 CT	MR Vista
	1200SX CT	Vistar Workstation
	Odyssey Nuclear	MR Edge
		MR Asset
		MR 2050
		MR HP
Toshiba		
	Access MR	
Fuji		
	AC 1	9000
	AC 2	
	AC 3	
Film Digitizers		
	Lumisys 100,150,200	

Display and Workstations "Teleshare 910"

These products comprise single-monitor high-resolution teleradiology displays, a dual-monitor high-resolution display with ISDN interface, and JPEG compression as well as a group of network-ready, DICOM-compatible workstations.

Lasershare 910

The Lasershare is a DeJarnette Research Systems PACSware system. PACSware systems are designed so

that they can operate on a number of independent platforms. The Lasershare is a modular system that uses network interfaces for communication between the modules, which can reside locally or remotely. The primary Lasershare modules are the Laser Spooler, Image Acquisition Server, and Printer Formatter. Other modules are Configuration and Debug modules.

The **Spooler module** is the control center of the Lasershare and is responsible for the system management, communication control, sheet generation and management (including printing), orphan control, and recovery management. System management maintains information about its resident Formatters in addition to information about other Spoolers and Formatters connected to the network. All communication between Servers, Formatters, and other Spoolers goes through the Spooler module.

The **Server module** is responsible for acquiring the image data and presenting the film information to the Spooler. This may require that the Server operate as a filming station. Its output is used by the Spooler to generate a sheet of film (such as the number of images, LUT's location of images on the film, annotation and overlays, etc.). Each server implements a single acquisition protocol. The Lasershare supports many server modules.

Each **Formatter modules** services a single printer. A Formatter is responsible for taking the sheet information generated by the Spooler and converting it into a format understood by the serviced printer. Each Formatter understands only one printer protocol. A Lasershare supports many Formatters.

The Lasershare provides Server modules for the following acquisition interfaces :

DICOM Print Management SOP
DICOM Point-to-Point Print Management SOP
DICOM Storage Class SOP
Video Frame grabbers
Siemens SPCI/SPDI camera interface
3M Laser Imager (P831) and Laser Imager Plus (M952)

KODAK EKTASCAN Laser Printer (KELP)
Polaroid Helios 810 Laser Imager and 14 × 17 Image Manager Lpr
Agfa Medical Digital Interface (AMDI)
Analogic DASM interface
PACSNET message storage

The Lasershare provides Formatter modules for the following printer interfaces:

DICOM Print Management SOP Class
DICOM Point-to-Point Print Management SOP Class
Siemens SPCI/SPDI camera
3M Laser Imager (P831) and Laser Imager Plus (M952)
KODAK EKTASCAN Laser Printer (KELP)
Polaroid Helios 810 Laser Imager and 14 × 17 Image Manager Lpr
Agfa Medical Digital Interface (AMDI)
Analogic DASM interface
Seike thermal dye sublimation printer
Harris Photo Pro 2000

SMALL-PLATFORM IMPLEMENTATION: PC & MACINTOSH

Merge Technologies Inc.

W. Stafford

Overview

Implementation of DICOM on small computer platforms involves challenges mostly related to the power of (resources available to) the operating system rather than processor capability per se. For the purpose of this discussion, PC-DOS, Mac System 7, and Windows 3.1 are the operating systems being considered. (There are a number of commercially supported UNIX implementations available for PC platforms that do not suffer from the same limitations of DOS, Windows, and Mac System 7. Windows NT [Microsoft] and OS/2 [IBM] are not considered herein, either, because they also can support resource-rich environments.)

HARDWARE AND SOFTWARE REQUIREMENTS

For a PC-DOS implementation, an 80286 central processing unit (CPU) with 1 MByte of memory and a Winchester disk are the minimum requirements. A faster processer and more memory can be utilized with good effect. PC-DOS 3.3 or higher and FTP's PC/TCP are required, the latter for provision of TCP/IP services that use a Berkeley Sockets interface.

For a Windows 3.1 implementation, an 80386 CPU with 4 MByte of memory and a Winchester disk are required. More memory and a faster processor result in less impact on other applications running concurrently.

On a Macintosh running System 7, best results are achieved with a 68040 CPU, although a 68030 CPU with a clock speed of 33 MHz can be utilized. MacTCP is required to provide the TCP/IP underpinnings and a Berkeley Sockets interface.

Supported DICOM Services.—DICOM implementation on small platforms has encompassed principally the storage service class of DICOM. These implementations have permitted acceptance and transmission of DICOM image objects by workstations (e.g., for use in image review or therapy planning), archival devices, and protocol converters.

DICOM Implementation Support.—Please see the following chapter on product information for specific information on support by Merge Technologies Inc (Merge) for both small- and large-platform implementations of DICOM-conformant applications.

PRODUCT INFORMATION

Overview

Merge develops and markets hardware and software designed to facilitate communication of diagnostic images over standard Ethernet networks.

Product Line

Merge's products can be likened to complementary "building blocks." The product line consists of:

1. Software "Tool Kits" designed for use on a variety of computer platforms:

MergeCOM	for implementing peer-to-peer image message handling and communications in ACR-NEMA version 2.0 format over TCP/IP Ethernet
MergeCOM-3	for implementing DICOM 3.0–conformant image message handling and communication within applications

Please see Exhibit 1 for a list of supported platforms and operating systems.

2. Hardware products that are self-contained devices composed of hardware and Merge proprietary software:

MergeMVP	a family of standalone interfaces, each of which converts a particular imaging device's proprietary protocol to an open Merge protocol or another proprietary protocol
MergeLFM	a network print server for laser imagers that accept MergeCOM or MergeCOM-3 (DICOM) print messages

Please see Exhibit 2 for a MergeMVP connectivity listing.

Merge image communication products allow "closed" systems, such as imaging devices, workstations, laser film printers, and even complete networks to become "open" and compatible with other imaging devices or networks.

Key to Merge's products are technology agreements Merge has in place with major imaging vendors, allowing Merge access to their proprietary protocols and formats. Under these agreements, OEMs have supplied Merge with the information required to create these products and the testing opportunities necessary for functional validation.

SOFTWARE PRODUCTS

Merge software products are based on industry-standard file formats and communications protocols developed by the ACR-NEMA collaborations. In addition to using these software components in Merge's own product line, Merge also provides Integrator's Tool Kits and Run-Time Licenses for system developers who wish to take advantage of Merge's connectivity experience.

ACR-NEMA 2.0 Software

MergeCOM is Merge's ACR-NEMA 2.0 communication tool. MergeCOM puts the industry's first standard image communication format onto TCP/IP Ethernet implemented in a peer-to-peer environment for point-to-point or network communications.

DICOM 3.0 Software

MergeCOM-3 is Merge's newest communication tool. MergeCOM-3 facilitates fully conformant implementation of the DICOM 3.0 standard. It is a significant technological advance over its predecessor, MergeCOM, but continues MergeCOM's role as the foundation of Merge Technologies' cross-vendor, open-systems connectivity strategy.

MergeCOM-3 embodies the industry-standard data format and communications protocol, DICOM 3.0. Connections can be as simple as point-to-point (between two devices) or as complex as a multmodality network of multiple devices. Used in conjunction with Merge's family of MergeMVP interfaces, MergeCOM-3 and related development tools can provide an environment of "open communications" between any and all of the imaging devices and peripherals in an imaging department.

The **MergeCOM-3 Basic Integrator's Tool Kit** provides the most fundamental DICOM capabilities and is designed to provide an easy upgrade implementation for current MergeCOM users. Basic MergeCOM-3 supports DICOM's storage service class (image transmission between devices).

The **MergeCOM-3 Advanced Integrator's Tool Kit** introduces a new API and supports all of the DICOM 3.0 service classes, including the storage service and:

- Query/Retrieve Service Class
  (a means of looking into another DICOM-conformant device and retrieving data);
- Basic and Advanced Print Service Classes
  (a means of formatting and sending image data to networked DICOM-conformant hardcopy systems); and
- HIS/RIS Service Class
  (a means of connecting to and exchanging demographic, scheduling, and other such data with DICOM-conformant information systems).

An overview of the Advanced Tool Kit follows this discussion as Exhibit 3. Tool Kit is user-friendly, supplying not only global defaults but a template-building capability for creating DICOM messages. Protocol data units are generated for the developer from a Merge-supplied table of presentation data values organized by SOP and DIMSE services. Extensive error detection and correction are enabled both with a "Validate" function, which validates the message's Type 1 and Type 2 elements against the standard, and with extensive communications and protocol debugging facilitated with detail configurable logging, useful both in validation of one's own development and also in validation with other implementations.

HARDWARE

Merge has developed a line of standalone "interfaces" and network "servers" that provide connectivity solutions to OEM's and end users. These hardware systems utilize

Merge software products in the internal data and communications conversions and depend on a close cooperation and with major imaging device manufacturers to affect connectivity to both imaging devices and image peripherals.

Protocol Converters

The **MergeMVP** (Multi-Vendor Protocol Converter) provides a means to connect a proprietary image producing device ("scanner") with other image-using devices or with a network. The "input to the MergeMVP" is an internal "module" that consists of hardware and Merge-proprietary software specific to the "personality" of the scanner. "Inside the MergeMVP" software converts the "closed" image information from the scanner into a uniform "open" format such as MergeCOM (ACR-NEMA 2.0) or MergeCOM-3 (DICOM 3.0). The "output of the MergeMVP" can be configured via an internal hardware andsoftware module with the "personality" of one of the standard Merge outputs (MergeCOM or MergeCOM-3) or proprietary output suitable for another vendor's image-using device or the network to which connection is being made.

The architecture of the MergeMVP allows Merge to accommodate diverse connection requirements by means of different combinations of Merge-developed modules. As an example, input modules currently available from Merge are shown in Exhibit 2. Additional modules will be added as market demand dictates.

Network Servers

The **MergeLFM** (Laser Filming Manager) receives image files from multiple image sources and executes pre-defined applications such as transferral of print jobs to laser imagers or paper printers. It enables the sharing of hardcopy devices by multiple image-producing or image-using devices across a standard Ethernet network.

PRODUCT SUPPORT

In addition to providing software and hardware and full support for these products, Merge also provides consulting and system integration services.

Consulting and Systems Integration

Merge provides a variety of services under a consulting umbrella called MergeLINK. The consulting program is provided to individual hospitals, health maintenance organizations, and imaging vendors that seek guidance in either planning for a future imaging network or actually building that network.

MergeLink consists of:

1. Sale of consulting on a time and expense basis, including researching the requirements to meet the user's expectations and applications (working with all vendors involved).
2. Provision of custom interfacing, if necessary.
3. Sale of system integration and installation on site (including location and subcontracting of local network cabling services).

Service and Support

Merge provides warranty and after-warranty service for both software and hardware products. Software revisions consisting of bug fixes and accommodations of vendor's software changes (vendor changes that affect interfacing or functionality) are provided free. Hardware products are warranted for 1 full year and repaired or replaced at the factory.

On-site trouble-shooting and service of Merge hardware products (MVP and LFM) is provided through modem

communication with the individual product or network of products. Merge provides on-site service and follow-up under contract with third-party service organizations.

EXHIBIT 1
Operation Systems/Platforms for Merge Software

MergeCOM:

- DOS — PC
- System 7 — Macintosh
- UNIX
  - Hewlett Packard
  - Silicon Graphics
  - Digital Equipment Corp. — Alpha
  - Sun OS 4.1.3
  - Sun Solaris 2.3
  - PC - BSD386
  - IBM RS 6000 - AIX
  - Convergent
- VMS - VAX

MergeCOM-3 Basic:

- DOS — PC
- System 7 — MAC
- UNIX
  - Hewlett Packard
  - Silicon Graphics
  - Sun OS 4.1.3
  - Sun Solaris 2.3
  - PC — BSD386
  - IBM RS 6000 — AIX
  - PC — QNX
- VMS — VAX (in process)

MergeCOM-3 Advanced:

- DOS — PC
- UNIX
  - Hewlett Packard
  - Sun OS 4.1.3
- Others to follow

EXHIBIT 2
Imaging System Connectivity

Manufacturer	Model	Merge Product	Modality Requirement	Status
Elscint	CT Elite	MVP-TE	Tape Drive	
	In Process			
	CT Elite	MVP	Ethernet	Planned
Fuji	CR AC1, AC2	MVP	SCSI	Planned
General Electric	CT 8800 (DG)	MVP-TE	Tape Drive	
	Installed			
	CT 9800 (DG)	MVP-TE	Tape Drive	
	Installed			
	MR Signa (DG)	MVP-TE	Tape Drive	
	Installed			
	CT Advantage	MVP	ID/Net v2.0	Installed
	MR Signa (Sun)	MVP	ID/Net v2.0	Installed
	CT Pace	MVP	Ethernet	Planned
	MR MAX	MVP	Ethernet	Planned
Hitachi	MR-5000	MVP	GPIB	Installed
	MR-7000	MVP	SCSI	Installed
	CT W1000	MVP	GPIB	Installed
	CT W2000	MVP	SCSI	Installed
Imatron	CT	MVP	GPIB	Planned
Philips	Philips PACS	MVP	DR-11W	Installed
	CX,TX,LX	MVP	GPIB	Installed
	CT 310, 350	MVP-TE	Tape Drive	Planned
	CT SR	MVP	SCSI	Installed
	MR S-15, T-5	MVP	GyroCom	Installed
	DSI	MVP-LP	Laser Camera Port	Installed
	GyroView	MVP	GyroCom	Installed
Picker	Q-Series CT	MVP	Ethernet	Installed
	Vista MR	MVP	Ethernet	In Process
Resonex	RS4000	MVP	Ethernet	Installed
Siemens	CT CR, DR	MVP	CT/MR Net	Installed
	CT Somatom	MVP	PACSnet	Installed
	Plus, Hi-Q			
	MR Magnetom	MVP	CT/MR Net	Installed
	MR Magnetom SP		MVP	
PACSnet				
	Installed			
	MR SP/4000	MVP	PACSnet	Installed
	MR Impact	MVP	PACSnet	Installed
	LiteBox	MVP	PACSnet	Installed
	Polytron	MVP-LP	Laser Camera Port	In Process
Toshiba	TCT 600	MVP	DR-11W/TDIS	Installed
	TCT 900	MVP	DR-11W/TDIS	Installed
	Xpress	MVP	Ethernet	
Planned				
	MRT 50,150	MVP	DR-11W/TDIS	Installed
	DFP 50,60	MVP	DR-11W/TDIS	Installed

EXHIBIT 3
MergeCOM-3 Advanced Integrator's Tool Kit

An Overview

The MergeCOM-3 Advanced Integrator's Tool Kit (Advanced Tool Kit) completes the evolution of the MergeCOM family of software to full support of the DICOM 3.0 standard. The Advanced Tool Kit is a cross-platform, scalable, simplified DICOM 3.0 solution for medical imaging application developers. In its initial release, the toolkit supports echo, storage, query/retrieve, and basic print services. Soon to follow are HIS/RIS and advanced print services. This document summarizes key features and design points of the Advanced Tool Kit.

Advanced Tool Kit Components

The Advanced Tool Kit consists of the following components (Fig 1):

1. A function library specific to the computer platform that is linked into the application being developed and supplies MergeCOM-3 Advanced Application Programming Interface to DICOM. This library does almost all of the "DICOM work."

2. Four user-editable configuration files:
   1. MERGE.INI Merge Initialization File
      Identifies product parameters, such as error logging parameters that specify the desired detail and location of error logging.
   2. MERGECOM.SYS System Profile
      Contains system and network parameters for the application(s) being developed; these parameters include supported transfer syntax, listen port, and network time-outs.
   3. MERGECOM.APP Application Profile
      For each remote DICOM application, this profile contains that application's title, host port and name, and a list of services that application requires or supports.
   4. MERGECOM.SRV Merge Service Profile

Contains a list of DICOM services the application supports. Only those standard services being supported need to be included.

3. A message object database in the form of binary files that describe the DICOM objects which the application(s) will communicate over the network. The code library uses this database at runtime to construct, maintain, and validate the instances of DICOM message objects that the application populates with data. The library then manages the exchange of these messages with other DICOM applications over the network.

4. A data dictionary, which is a binary file that contains a data dictionary of all DICOM attributes and their respective data types. This file is also used by the code library for the proper formatting and validation of messages.

For developers who need to extend DICOM by defining their own private services (SOP classes) and message objects, Merge will supply a Microsoft Windows–compatible database application that facilitates extension of the standard DICOM information objects and SOP classes with private attributes or definition of private SOP classes. Included with this database are applications that generate the run-time binary message object database and data dictionary files.

KEY FEATURES

Scalability

The Advanced Tool Kit is highly configurable to better utilize resource-rich systems (such as UNIX workstations) while not ruling out lower-end platforms (e.g., DOS or Windows). For example:

1. The message object database and data dictionary can be read into memory at application startup or read

from the file system on an as-needed basis.

2. As large data attributes (such as pixel data values and overlays) arrive or depart over the network, they can be throttled directly by the application a "chunk" at a time through callback functions specified by the developer. If a callback mechanism is not specified, the toolkit stores the large data automatically, either in memory or temporary files (configurable).

3. The runtime message object database need only contain the objects for the DICOM services your application requires. This means that highly specialized applications can run with the smallest possible message object database in primary memory.

Flexibility

If the DICOM 3.0 standard does not supply services (SOP classes) specific enough to a developer's needs, the standard message object database and data dictionary can be extended to support private attributes directly through the API at runtime. If private SOP classes that differ significantly from any of the DICOM standard SOPs are required, Merge provides a message object database maintenance application for Windows to facilitate creation of the needed special runtime message object database.

Simplicity

The Advanced Tool Kit API is powerful yet simple:

1. Register the application with the Tool Kit library using
   MC_Register_Application( ).

2. As a client, open a connection with a DICOM server with
   MC_Open_Association( )
   or, as a server, wait for a connection from a DICOM client with
   MC_Wait_For_Association( ).

3. Create a DICOM message object with
   MC_Open_Message( ).

4. Fill in the message object using the **MC_Set_Value( )** family of functions.

5. Parse a message object using the **MC_Get_Value( )** family of functions.

6. Send messages over the association that has been opened with
   MC_Send_Message( )
   and wait for messages with
   MC_Read_Message( ).

7. Validate a message constructed or received by the application against the DICOM standard or private service definitions with
   MC_Validate_Message( ).

8. Declare callback functions, define private attributes, stream DICOM messages to and from message objects, and so on with other Advanced Tool Kit functions.

Portability

The Advanced Tool Kit is object-oriented in design and written in ANSI-C to maximize portability and performance. The earliest releases are for POSIX/UNIX and DOS platforms. Ports to Windows, Windows NT, OS/2, and the Macintosh will be available in the near future. Other ports will be accomplished based on demand and require only that the platform support an ANSI-C compiler and a Berkeley Sockets (or WinSock) interface to TCP/IP.

The Advanced Tool Kit is designed so that moving to transport layers other than TCP/IP and Sockets (e.g., Streams or TLI) can be accomplished in a straightforward manner as requirements arise.

CHAPTER 5
Appendices

A. Glossary

Abstract syntax generic term, by DICOM 3.0 implemented as SOP syntax

ACR American College of Radiology

Access protocol traffic rules to establish association and avoid collision

ACSE Association Control Service Element used to establish an association

ANSI American National Standards Institute

Application context identifies the overall communication context

Application entity (AE) a DICOM-conformant agent on the network

Association a network connection

Attribute a property of an item

Byte ordering see Endian

CEN TC 251 Comité Européen de Normalisation Technical Committee 251

Client server network terms for specific roles, equivalent to SCU and SCP

Command information item requesting an action

Composite object representing more than one real-world object

Conformance Statement part 2 of the DICOM standard specifying performance

Data dictionary part 6 of the DICOM standard

Data element a subunit of an information object

DIMSE DICOM Message Service Elements, functionality capable of generating type 4 PDUs

Domain an Internet zone of authority, part of the address structure

Element types

1	required; must have value representation and non-zero length
1C	conditional 1
2	must be listed but can have zero value and zero length
2c	conditional
3	user defined, optional

Endian defines the byte ordering

Little Endian orders the byte sequence with the least significant byte first, the most significant last. Big Endian orders bytes in the reverse sequence. Endian ordering applies only to numbers. Text strings are represented by ASCII bytes in the sequence of letters or symbols.

FDDI fiber-distributed data interface, high-speed network (used for *info*RAD 1993 demonstration)

Film session a group of films

Frame a data packet

Gateway device and conversion method between heterogenous networks or systems

HL 7 High Level 7, an ANSI member, dealing with HIS development

IEEE Institute of Electrical and Electronic Engineers

Instance a representation of a class

Information objects structures of object-oriented design

Internet a collection of networks and gateways, including ARPnet, NSFnet, MILnet, and others.

IOD information object definition

IP Internet Protocol (takes care of addressing and makes sure routers know what to do with the data)

ISO International Standards Organization

Message a structured data unit for communication. It is divided into PDUs according to part 8 of the DICOM standard (for network communication)

Module a group of data elements

OSI Open System Interconnection (model developed by the ISO)

Packet structured data sets usually between 1 and 1,500 characters long

PAD packet assembler/ disassembler, an X.25 term

PDU protocol data unit, the transported structure of information

Port computer ports are I/O channels of communication (for instance, serial or parallel ports); Internet ports are protocol types

Presentation context consists of abstract syntax and transfer syntax

Protocol in OSI terminology, data format for peer-to-peer communication

Routers path switches of computer networks

Service Class Provider (SCP) a role of an AE corresponds to **Service Class User** (SCU), similar to server and client in network terminology

Stack a set of lower OSI layer protocols (for instance, TCP/IP or OSI)

SMTP simple mail transfer protocol, usually part of TCP/IP

SOP service-object pair combining command and data information

SQL structured query language

TCP transmission control protocol divides the PDUs (protocol data units) into sequences of packets and, at the receiving end, reassembles these packets into PDUs

Telnet a terminal emulation program of TCP for remote log-in

Transfer Syntax defines coding (for instance, as big Endian)

UID unique identifier of information objects and services

VR value representation, one of the 24 coding methods specified in part 5 of the standard

B. Healthcare Informatics Standards Planning Panel

The Healthcare Informatics Standards Planning Panel (HISPP) was formed after a meeting in March 1991 by representatives of the U.S. government, specifically the Food and Drug Administration (Dr. M. Greberman), Agency for Healthcare Policy and Research (Dr. M. Fitzmaurice), a representative of ANSI, representatives of ACR and NEMA, and a representative of Comité Européen de Normalisation (CEN) (European Standards Committee) (Dr. G. De Moore of Belgium). Dr. C. McDonald of the Indiana School of Medicine chaired the meeting. Two topics were discussed :

- Formation of a broad U.S. organization capable of coordinating the many standarization activities in health care.
- Formation of a group authorized to work with CEN TC 251, the technical committee that deals with health care informatics, toward "harmonization" of U.S. and European health care informatics developments.

At a later meeting the scope of HISPP was defined as comprising :

1. Health care models and electronic health care records;
2. The interchange of health care data, images, sounds and signals within and between organizations and practices;
3. Health care records and terminology;
4. The communication with diagnostic instruments and health care devices; and
5. Additional areas of concern or interest with regard to health care.

The objective was stated as follows:
"Coordinating the work of standards group ... toward achieving the evolution of a unified set of non-redundant, non-conflicting standards that are compatible with ISO and non-ISO communication environments."

Now, 3 years later, a large body of standards-writing organizations addresses major isssues such as

- A computer-based patient record
- Message communication
- Code and vocabulary
- Privacy, security, and confidentiality
- Provider identification

The activities of ACR and NEMA, in particular the development of the DICOM standard, fits well into the "Message Communication Task Force" and are indeed seen as an important contribution.

Participating standards-writing organizations are the American Dental Association; American Health Information Management Association; ASC X3, which deals with databases, file formats, and communication protocols; ASC X12N, which deals with insurance; American Society for Testing of Materials, which has been active for many years in the general area of health care informatics; Health Level Seven, which addresses hospital information systems; Institute of Electrical and Electronic Engineers with the development of Medical Information Bus and the Medical Data Interchange standard; NEMA; and others.

The HISPP, an ANSI organization, is authorized to represent U.S. standard activities vis à vis CEN through its membership in ISO. This relationship has facilitated acceptance of the DICOM standard by TC 251 as a basis for the European MEDICOM development. The participation of European CTN developers in the 1993 *info*RAD demonstrations was evidence of such acceptance. DICOM representatives and TC 251 representatives have met in the past and will continue to meet in the future. The common goal is an international standard for health care informatics.

C. CEN Technical Committee 251

In July 1989, the Senior Officials Group on Information Technology Standards of the European Community issued a mandate for a study of what is being done and what should be done in the field of medical informatics standards. The mandate was passed to the European standardization bodies CEN, CENELEC, and ETSI, and after consultation with the national standards bodies, the work was divided into two sections.

Part A, which is concerned with the informatics issue, was assigned to CEN/IT Project team 001, and part B, which is concerned with the applications of the open systems standard, was assigned to the European Workshop for Open Systems (EWOS) Project Team 007.

In spring of 1990, CEN established Technical Committee 251 on "Medical Informatics" with representatives from all 18 member organizations. TC 251 is chaired by Professor George de Moore, of Belgium. The two project teams (CEN and EWOS) are working under the guidance of TC 251.

The two project teams suggested development or adoption of a set of European standards (EN standards) and agreed on a common taxonomy for the work items. There are 48 work items defined in the CEN report and 42 work items in the EWOS report. However, some of the work items in the two reports are identical.

Within the scope of applications imaging is possibly the most important one. It attracts the attention of a large number of people. All proposals to CEN that have to do with imaging are based on the ACR-NEMA standard.

The following is an excerpt of a report of one member of WG 4, TC 251, made in November 1990:

Working Groups of TC 251

WG 1	Health Care Information Modelling and Medical Record
WG 2	Health Care Terminology, Semantics and Knowledge Bases
WG 3	Health Care Communication and Messages
WG 4	Medical Imaging and Multimedia
WG 5	Medical Devices
WG 6	Health Care Security, Privacy, Quality and Safety
WG 7	Intermittently Connected Devices

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